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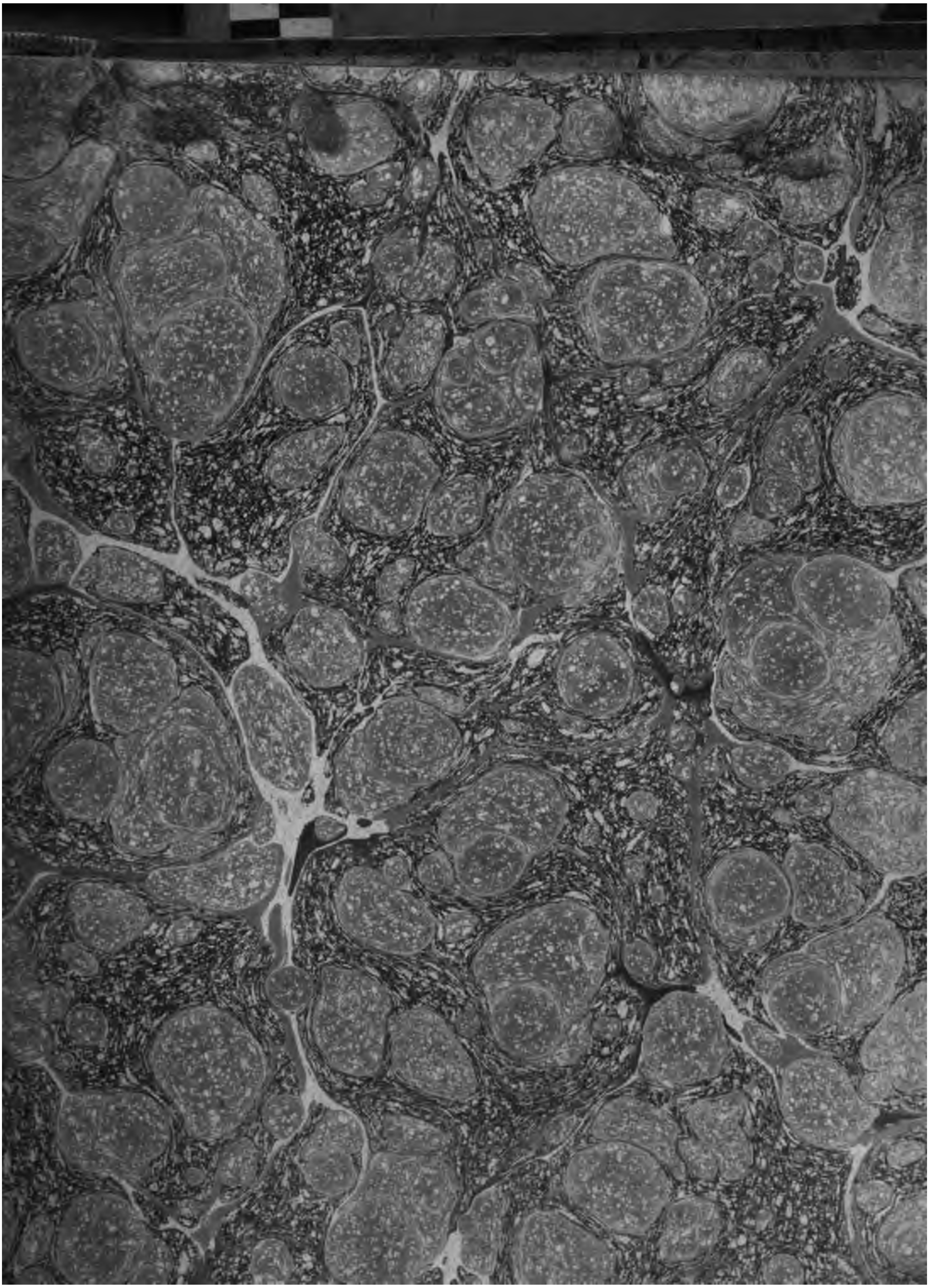

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ORGANIC REMAINS OF A FORMER WORLD.

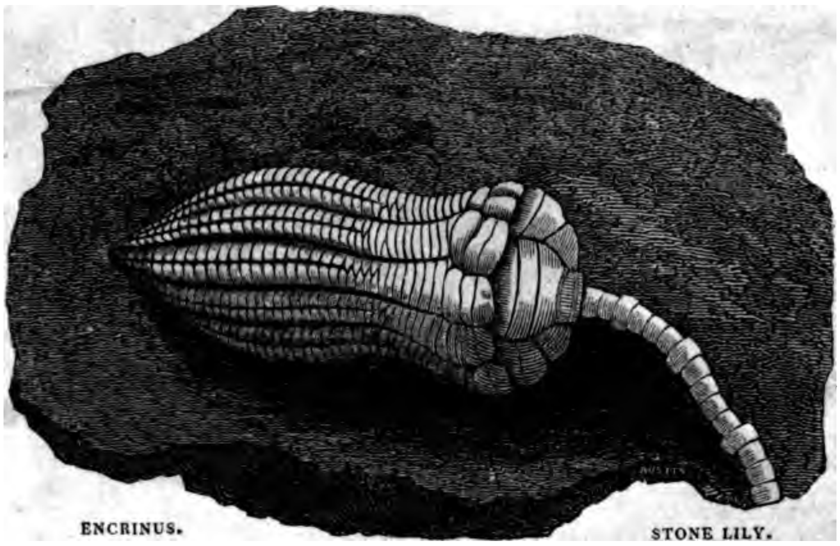
AN

EXAMINATION OF THE MINERALIZED REMAINS OF THE *VEGETABLES AND ANIMALS* OF THE ANTEDILUVIAN WORLD;

GENERALLY TERMED

EXTRANEOUS FOSSILS.

By JAMES PARKINSON, Hoxton.



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CONTAINING
THE VEGETABLE KINGDOM.

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TO

WAKELIN WELCH, Esq.

OF

LYMPSTON, IN DEVONSHIRE,

THIS WORK

IS DEDICATED,

IN TESTIMONY OF THE FRIENDSHIP AND RESPECT OF

JAMES PARKINSON.

and opinions, of preceding writers, whether foreign or domestic, he was therefore disposed to take on himself the task of accomplishing, to the best of his abilities, a work of that description. Numerous difficulties, indeed, offered themselves to his apprehensions; but these, he trusted, might yield to an almost enthusiastic fondness for these pursuits. Many errors and defects, he feared, might obtrude themselves on the eyes of the discerning critic; but these he hoped might, in some measure, be compensated for, by the peculiar information which would result, from the frequent examination of a tolerably large and systematic cabinet, obtained from the collections of Mr. Strange, Lord Donegal, and Mons. Calonne.

The kind encouragement of his scientific friends prompted him to apply himself to the task; but the doubts and hesitations of those, most in the habits of estimating the success of the offspring of the press, almost induced him to relinquish his proposed intention. His arguments in favour of the attempt, derived from the circumstance of the publications on this subject being so very few, were powerfully rebutted by the inference, that there were therefore but few readers; and, consequently, but a small demand could be expected. Partiality, however, to the project he had formed, and a conviction that ample support might be obtained, were the attention of the public fairly called to the wonders, which the study of oryctology discovers, made him resolve on the attempt.

But, aware of the small number of those who, at present, make this science their study, he feared that a dry, strictly scientific, work obligations to that friend of science, Sir Joseph Banks, to Dr. James Edward Smith, President of the Linnæan Society, W. H. Pepys, Esq. and other gentlemen, will be fully acknowledged in the body of the work.

That the matter of the present volume will be found highly interesting is confidently hoped; but when the vast variety of the animal kingdom is considered, it is not too much to promise, that the subsequent parts of this work will far exceed, in this respect, the present; and cannot fail to yield to the admirers of Nature's works considerable gratification.

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ORGANIC REMAINS
OF A
FORMER WORLD, &c.

LETTER I.

RATIONAL APPLICATION OF WEALTH AND LEISURE......SNAKE-STONES......FAIRIES CHANGED TO SNAKES......FAIRIES NIGHT-CAPS......BONES OF GIANTS......THUNDERBOLTS.

I HAVE long been of opinion, that a considerable portion of wealth; the fruit of anxious and laborious exertions, would yield, comparatively, but little enjoyment; unless, during the time devoted to its acquirement, care had been taken to fill up some of the leisure hours, which business could spare, with such amusements, as would form and cultivate a taste for truly rational pleasures. I am now convinced, that unless this be done, wealth and leisure, instead of producing to the man of business the completion of his happiness, will frequently prove to be the source of perpetual torment. The mind, deprived of its usual entertainment, and not trained for the adoption of any new mode of exercise, either lapses into the dreadful torpor of hypochondriacism; or seeks to obtain a temporary gratification from pursuits, unworthy, from their frivolity, or from their vicious tendencies, to be adopted by a being, endowed with reason.

I have lived long enough, to have repeatedly witnessed similar terminations of the dreams of happiness, which have deluded those men of the world; who, intent only on the acquisition of money, have supplied their minds with so little information; that they possessed not the means of using, as a blessing, the hardly earned wages of a life of care.

Influenced by such observations, and aware of the necessity of obtaining such resources, I have, therefore, always allotted a small portion of my time to such pursuits, as have, at least, excited a disposition to scientific research, and an enthusiastic admiration of the beauties of nature. With my mind thus furnished, I have ventured to avail myself of the opportunity, which my little fortune affords me; and have, I trust, quitted the busy part of the world for ever.

In pursuance of a plan, on which I had long determined, of visiting the most interesting parts of this island, I quitted London, last week, with my daughter, accompanied by our old friend WILTON, whose lively manners, as you well know, render him an excellent companion. But he has made himself highly estimable to us on another account: his resolute scepticism, with respect to the more rational; and his submissive credulity, as to the more popular explanations of such natural phenomena, as are beyond the reach of his understanding, are frequently productive of remarks, so full of quaintness and of humour, as to render them, in the highest degree, amusing.

Our first day's journey was not completed, before I discovered, that the little knowledge, which I had obtained, was insufficient to enable me to form, even, a conjecture, respecting the origin of the very first object, which particularly attracted our attention. We were within about ten or twelve miles of Oxford, when WILTON, looking out of the window of the chaise, exclaimed, "Well, I never saw roads mended with such materials as these before!" This, of course, drew my attention to the same object, which had so strongly engaged his; and I am confident, that the astonishment excited in my mind was but little, if at all, less than that which possessed our friend; when I beheld a labouring man breaking to pieces, with a large hammer, a stone nearly circular, half as large as the fore-wheel of our chaise, and bearing the exact form of a serpent closely coiled up. Curiosity prompted me to stop the chaise, and to ask the man the name of the stone, and where it came from. "This stone, sir," says he, "is a snake stone, and comes from a pit in yonder field; where there are thousands of them." We all alighted, and with surprise examined some of the same species of stones, which he had not yet broken; and which, though evidently bearing the form of some strange animal, were undoubtedly formed entirely of stone.

As we sauntered along, the chaise following us, we came to a neat, though a small house, on the road side; which a sign, stuck in the hedge, on the opposite side of the road, taught us was a house of public entertainment. Hoping to gain some farther information, respecting that which had so strongly attracted our notice, we entered this, literally, hedge ale-house. But when introduced into a very neat room; the casement of which, surrounded by roses and honeysuckles in full bloom, opened into a garden, rendered charming by the wild luxuriancy and profusion, with which its various productions displayed themselves to our view; we had very little hesitation in determining to stop, and partake of such refreshments, as our cottage would yield. Whilst these were preparing, WILTON, who was examining the furniture of the old oaken chimney piece, said, "Well, if the object of travelling is to behold novelties, surely this country will yield that gratification, in the highest degree; for among the various things with which this mantle-piece is ornamented, there is not one, of which, I have ever seen its like." They now passed under my examination, but with equal ill success: for neither had I ever beheld any thing similar; nor could I form any opinion respecting them.

Whilst we were thus engaged, our landlady made her appearance; and from her we learnt, that this was her *collection of curiosities*, made in the neighbouring parts of the country. On our requesting some information respecting them, she very readily proceeded to communicate to us, all the knowledge of them which she possessed. Taking up a stone, resembling those which we had seen in the road, but much smaller, "This," said she, "is a petrified snake, with which this part of the country abounds. These were," continued she, " fairies, and once the inhabitants of these parts, who for their crimes were changed, first into snakes, and then into stones. Here," said she, shewing us a stone of a conical form, " is one of the *fairies night-caps*, now also become stone Do, madam," said she, addressing Emma, "pray observe; is it possible that lace-work, so beautiful as this, should ever be worked by human hands? This," said she, "and this, are pieces of the *bones of giants;* who came to live here, when the race of fairies was destroyed." These bones, she informed us, were frequently dug up in several parts of the county; as well as innumerable *thunderbolts:* some of which she also shewed us; stating, that these were the very thunderbolts, with which these people were, in their turn, also destroyed.

We all listened attentively to our hostess's discourse; but on my smiling, when she withdrew, at the romantic account we had received, Wilton strenuously defended our good lady's narration; and declared, that, in his opinion, it was not without a moderate share of probability. On our landlady again entering the room, I did not indeed venture to offer any doubt of the history she had delivered; I only requested to know, whether she knew of any larger collection of the same kind? " To be sure," said she; "our university has a museum composed entirely of this kind of curiosities;

and if you be going through Oxford, it will, I dare say, be well worth your while to take a view of them."

When we had finished our refreshment, we left our kindly communicative hostess; but not, as you might suppose, with any intention of immediately visiting the Museum of the University. On the contrary, we were aware, that, without some previous knowledge of the objects, which are there exhibited, the examination of them could not yield much satisfaction; but would serve, merely, to excite that curiosity, which it was not able to gratify. We have therefore settled it, that our visit to the Museum shall be deferred, until we are enabled to view its interesting contents with that satisfaction, which can only be yielded, when we possess some knowledge of the objects we contemplate.

Thus, at our very outset, have I experienced a considerable disappointment. The objects I have already seen; and which I have reason to expect I shall frequently meet with, have convinced me, that I am totally ignorant of the science, which teaches us their natural history: and also that, without this knowledge, the pleasure of my journies must be very much diminished. How mortifying will it be to have objects presented daily to my view, whose form alone renders them highly interesting; and whose history is most probably fraught with entertainment; and to find myself so totally ignorant of their origin, as not even to know in what class of nature's works to place them.

You, I know, have long made this branch of natural history your particular study: and I have been informed, that you possess a collection of valuable specimens of these substances, which it has never occurred to me to request the inspection of. To you, therefore, I confidently apply; and earnestly intreat you to supply me with a regular, and systematic history of these strangely figured substances; to understand the nature of which, I am impelled by the most eager desire. The petition I am making will, I trust, be favourably attended to; when you consider, that, without your assistance, the pleasure I have promised myself, in my long-proposed tour, will be considerably diminished: for what, to an inquisitive mind, can be more mortifying, than to have the curiosity excited to the highest pitch, without acquiring a single point, on which even conjecture may be founded.

LETTER II.

VESTIGES OF THE INHABITANTS OF A FORMER WORLD......LIMESTONE AND MARBLE......MEDALS OF CREATION......PLEASURES AFFORDED BY THIS SCIENCE......ANIMALS IN THE FORMER WORLD, DIFFERENT FROM THOSE OF THE PRESENT.

To comply with the request you have made, will give me real satisfaction; since, I am confident, should my endeavours prove equal to the undertaking, that I shall open to you a source of inexhaustible pleasure. For, not only the country through which you are now journeying, but the greater part of this island; and even of the globe, teems with these curiously-formed stones: the remains of those beings, which, many ages since, depended, for their existence, on the various energies of vegetable or animal life. These bodies, every atom of which they are constituted existing in a different state of combination, from that in which they were originally disposed, often retain, nearly, the exact figure which they bore in their primitive state. But the forms which they present to our view are, frequently, so different from any organized being we have any knowledge of; that their appearance cannot fail to excite an enthusiastic admiration; and an eager desire to obtain all the information, respecting them, which can be acquired.

Notwithstanding the interest which they must excite, want of information, respecting these bodies, generally prevails. Even in those places in this island, where they most commonly are found, all enquiries respecting them are, in general, answered only by the most silly tales and legends. This is, perhaps, attributable to the circumstance of no particular treatise, on these subjects, having yet appeared in the English language; excepting a few valuable papers in the Philosophical Transactions: Dr. Woodward's Catalogue of his Collection of Fossils: Mr. Walcot's Description and Figures of Petrifactions, found near Bath: some observations in Mr. Jones's Physiological Disquisitions: and Mr. Martin's Figures and Descriptions of Petrifactions collected in Derbyshire. What else has hitherto been published, in this country, respecting them, has been chiefly in those works, which, treating of mineralogy in general, have necessarily spoken of these substances, but in a most superficial and unsatisfactory manner. In France and Italy, and more particular in Germany, the most ardent and scientific enquiries have indeed been instituted; in consequence of which, discoveries of the most curious and interesting nature have been made. These, however, having been published either in French, German, or Latin; and not having yet appeared in an English dress, it is not to be wondered at, that the astonishing information which they impart, is so little known in this country.

From the consideration of this circumstance, I am disposed to offer to the public eye whatever information I shall be able to collect, whilst complying with your request; trusting that the interest, excited by the subjects of my enquiry, will be sufficient to awaken attention to a most pleasing, but much neglected, science.

The illustrious Bergman elegantly describes fossils, as the MEDALS

OF CREATION; and, indeed, a very little advancement in the study of this science is necessary, to discover the peculiar propriety of the application of this term, to the subjects of our present enquiry.

By these medals of creation we are taught, that innumerable beings have lived, of which not one of the same kind does any longer exist—that immense beds, composed of the spoils of these animals, extending for many miles under ground, are met with in many parts of the globe—that enormous chains of mountains, which seem to load the surface of the earth, are vast monuments, in which these remains of former ages are entombed—that, though laying thus crushed together, in a rude and confused mass, they are hourly suffering those changes, by which, after thousands of years, they become the chief constituent parts of gems; the limestone, which forms the humble cottage of the peasant; or the marble, which adorns the splendid palace of the prince.

Surrounded, as we are, by the remains of a former world, it is truly surprising, that, in general, so little curiosity and attention are excited by them. Wherever civilized society exists, these wrecks of the earliest ages may be found, yielding to man the most important benefits. Changed in their appearance, during the revolution of innumerable ages, they sometimes manifest but slight traces of their former modes of existence: and, having already performed several important offices in the economy of nature, they are now offered to man, as powerful inducements to the exercise of industry; and as fit materials, on which his faculties may be exerted. Varying infinitely in their nature and substance, according to the combinations into which they have entered, they become useful to man in numberless ways.

Not the smallest or rudest village is to be seen, in the neighbourhood of a limestone-mountain or quarry; but it may be discovered that these have been ransacked to furnish the foot-path, or to aid the erection of the poor man's dwelling. In visiting the mansions cesses, serving to support animal life; and the infinitely-varied modes of organization, which exist even in the same being; cannot fail to excite an eager desire, to obtain still further knowledge, respecting those astonishing operations; in which, although the effects are so obvious and even palpable, the immediate causes demand the closest investigation for their discovery. In consequence of this, although the mind obtains a considerable fund of pleasing and positive instruction, it is so far from experiencing the torpor of satiety; that it looks forward, with increased ardour, to the extension of its acquisitions.

The science, into the study of which I propose to lead you, also possesses these advantages, in a very eminent degree. You will be taught, clearly, by it, that the formative and preservative powers, appointed by the Almighty, are momentarily exerted on the smallest particles of matter: that nature, by which I mean the personification of these powers, is constantly employed also on the largest, and apparently most inert masses of matter; in accomplishing the several processes, necessary for the support and continuance of the earth, and its inhabitants. You will behold her, incessantly labouring in the deep recesses of the earth; as in the laboratory of the universe, reducing to form and beauty, the mutilated wrecks of former ages.

Nor can the mind be much more pleasingly exercised, in the regions of conjecture, than by the curious inquiries to which the contemplations of objects, so interesting, must necessarily lead. Many of the curiously figured stones, which will offer themselves to your observation, you will be pleased in finding, on a close observation, were once, as I have already remarked, beings endowed with the powers and faculties of vegetable or animal life. You will, by careful comparison, discover, that, of these, several species are still to be found, in a living state; but, most commonly, in parts of the world very remote from those, in which their remains are thus wonderfully preserved. Other animals you will find thus astonishingly entombed, possessing, indeed, many of the anatomical characteristics of animals now existing; but differing so much, in other respects, as to require to be considered, as entirely different from any which are known now to exist. Thus you will behold the bones of an animal, of which the magnitude is so great; as to warrant the conviction, that the bulk of this dreadful, unknown animal, exceeded three times that of the lion; and to authorise the belief, that animals have existed, which have possessed, with all the dreadful propensities of that animal, its power of destroying, in a three-fold degree. You will also view the remains of a being of the magnitude, at least, of the elephant; which was armed with tusks, equally dreadful, as a weapon, with those borne by that animal; and possessing, in addition to these, enormously huge grinders, supposed to bear the distinctive marks of those creatures, which gain their food, by preying on those of inferior powers and size. The jaws of an animal bearing a near resemblance to those of a crocodile, you will perceive to be armed with teeth, not widely different from those of the shark. In a word, you will be repeatedly astonished by the discovery of the remains of animals, of which no living prototype is to be found.

When the mind has dwelt awhile on objects so well calculated to impress it with astonishment, fresh subjects for conjecture, and most interesting contemplation, will arise. The number of these wrecks of a former world, must, as well as the situations in which they are found, excite the highest admiration.—Not in one particular spot—not in one region—not in one quarter of the globe alone—but wherever this world has been explored. In the greatest subterraneous depths, in the bowels of mountains, and on heights vastly above the level of the sea, are these wonderful remains to be found. But enough——I have pressed so far on, as to be under the necessity of craving your indulgence, for credit, for the proofs of what I have already stated, which I promise satisfactorily to produce.—In the mean time, surely I may presume that you begin to perceive, that this part of natural history possesses importance sufficient, to claim a very considerable degree of attention. To confirm you in this opinion, I must add, that by these studies a more perfect knowledge is gained of the internal structure of this globe; of its ancient state; and, of the various and important changes it has suffered.

By widening the views of the natural philosopher; by opening to him, fresh fields of observation; and, by showing him a glimpse of other creations; more just, and more grand sentiments, also, must be excited, of the immensity of animated nature, and of the power of the great Creator of all things.

In pursuing these investigations, I shall, in general, adopt the following order. The fossil, in its present state, will be carefully described; and, whenever it can be done, the situation in which it is found will be pointed out; its primitive mode of existence, and the various properties which, by analogy, may be supposed to have characterised it in its living state, will be enquired into; and the several changes which it has undergone, both in its composition and its structure, will be carefully examined.

The wonderful changes of situation, which the various objects of investigation will be found to have undergone, will necessarily demand an assiduous enquiry. The endeavour to furnish some satisfaction on this abstruse and interesting subject, will be reserved, as much as may be, for the concluding part of our enquiries. This place it will occupy, with the most propriety; since the several facts and observations, detailed in the preceding part, will furnish some of the *data*, which are to serve as the foundation for the reasonings, and conjectures to be advanced here. It is proper, however, in this place, to remark, that, on this subject, but little positive knowledge can be acquired; and that probable conjecture, even after the most assiduous enquiry, is the highest degree of satisfaction to which the mind can possibly attain. Indeed, the attempt to account for the astonishing appearances, which the surface of this globe presents, may appear to many, as indicating a very improper degree of confidence and presumption.

To trace the operations of nature, in periods far behind all human record; to pronounce opinions respecting the structure and the inhabitants of a former world; and to endeavour to find out the ways of God in forming, destroying, and reforming the earth; does certainly appear to be a task, to which the limited powers of man are but little adapted. But, since the world we inhabit is evidently composed of the wrecks of a former world; the materials of which that world was composed are, of course, at hand for our examination. The remains too of its former inhabitants are frequently found preserved, in such situations as teach us something, not only respecting the extent of the changes, which have taken place on the surface of this globe; but even the particular element which was employed, as the chief instrument of destruction, and of renovation. Scripture, likewise, corroborated by the collateral evidence of all human tradition, supplies us with the grand leading facts; that, after the complete formation and the peopling of this globe, it was subjected to the destructive action of an immense deluge of water; all the fountains of the great deep were broken up; the high hills that were under the whole heaven were covered; and every living substance was destroyed, which was on the face of the earth. Chemistry and mineralogy also furnish us with their aid, by which we are taught the several changes of which these substances, under various circumstances, are susceptible.

By these aids, we may sometimes be enabled to form, perhaps, a tolerably correct judgment, respecting some of the grand changes which took place, during the vast revolution which this planet has experienced. But so very remote is the period, to which our minds are to revert: so loose, and so light, are the grounds on which our conjectures are to be built: and so great is the temptation to imagination, to take the place of judgment, that, among the several systems, of which I shall have occasion to make mention, you, not only, will hardly find one on which you can venture to depend; but you will discover, that the majority, so far from possessing even probability, rather resemble the fictions of poets, than the reasonings of philosophers.

Yours.

LETTER III.

EARLY EXISTENCE OF THESE SUBSTANCES......NOTICED BY XENOPHANES, HERODOTUS, ERATOSTHENES, STRABO, PLINY, OVID, &c.......SKETCH OF THE HISTORY OF THE SCIENCE.

A SLIGHT review of the history of what has been hitherto accomplished, in the endeavour to promote, and diffuse the knowledge of these subjects, cannot, in itself, but be highly interesting. At the same time, it will shew the necessity of such a work, as is here attempted; in which a summary account is intended to be given of the several discoveries and opinions, which have, at different periods, been published; since, by thus placing them by each other, in a fair point of view, a proper judgment may be formed of their respective merits, and useful truths may be the result of the comparisons thus made.

In the earliest philosophical writings, which have been transmitted to us, numerous proofs are to be found, that the existence of substances, which had undergone the process of petrifaction, had not, in those ages, escaped observation.

Xenophanes, the founder of the Eleatic sect, who wrote upwards of 500 years before Christ, maintained that God and the world were the same; and contended for the eternity of the universe. In support of the latter opinion, he dwelt much upon the circumstance of petrified shells being found, in the internal parts of mountains, and, in the bowels of the earth. He related, that, in the quarries of Syracuse, the impressions of fishes existed; that the impression of a small fish was found, deeply imbedded in a rock at Paros; and, that almost every species of marine animals had been thus preserved: he inferring, from the appearance of these extraordinary phenomena, that these places must, in very distant ages, have been covered with the sea*.

Herodotus, who wrote 440 years before Christ, speaks† particularly of shells existing in the mountains of Egypt; and concludes, from this circumstance, and the saltish emanations which injured the pyramids, that the sea had gradually retired from these parts.

Theophrastus was supposed to have written a book, entirely on petrifactions; and which, though ranked among his lost works, was imagined to have been in the possession of Pliny; and to have yielded him some portion of assistance, in that part of his Natural History.

Eratosthenes, who lived 200 years before Christ, when enquiring into the figure of the earth, also considered it as a question worthy of investigation—How it could have happened, that vast numbers of oyster, and other shells, should be found scattered in many places, at a very considerable distance from the sea. This phenomenon had also been noticed by Strato, and by Xanthus of Lydia, as well as by Strabo himself; who refers to, and corroborates their remarks, in the first book of his Geography; particularising some of the species of shells thus changed, and the places where they were found.

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* In Originis Philosophumenis, cap. xiv. p. 100.

† Lib. ii. sect. xii.

That these substances, which had undergone this extraordinary change, existed upwards of two thousand years since, in quantities so considerable as to have excited the attention of the Grecian philosophers, is therefore very evident. So prodigious and so extensive were the effects they noticed, that we find almost all of them contending for the eternal duration of the world; finding it difficult to conceive any period of time, in which changes, so vast and extraordinary, could be accomplished.

The Romans, more disposed to cultivate the fine arts, and to encourage works of genius and imagination, did not pursue the study of natural history with much avidity. Excepting in the works of Pliny, but little of originality is discovered in the writings of their natural historians. They appear to have contented themselves with merely preserving the discoveries of the Greeks; neither seeking to add to the stock of facts, which had been already collected; nor, by their researches to ascertain, what degree of reliance might be placed, on the various histories of nature which had been transmitted them.

In the works of Pliny, who wrote near 1800 years ago; and in that part of his writings, which probably are considerably indebted to the lost work of Theophrastus, who wrote about 300 years before Christ, we find mention is made of several substances, which future observation has taught must have undergone the process of petrifaction. Among the most remarkable of those of which he speaks, is the *Bucardia*, like to an ox's heart—*Brontia*, resembling the head of a tortoise, supposed to fall in thunder-storms—*Glossopetra*, like to a human tongue; which does not grow in the earth, but falls from heaven whilst the moon is in its wane—*Hammites*, like the spawn of fishes—The *Horn of Ammon* possessing, with a golden colour, the figure of a ram's horn—*Lepidotes*, which imitates, in various colours, the scales of fishes—*Meconites*, resembling the poppy—

Ceraunia and *Ombria*, supposed to be thunderbolts—*Ostracites*, which, though harder than shell, bears the name and resemblance of the oyster—*Syringites*, which is formed with cavities, by which it resembles the pipes of straw—*Spongites*, bearing the form of sponge —*Phycites*, resembling sea weed or rushes.

He also speaks of a black light substance, resembling wood; of stones, resembling the teeth of the hippopotamus; and observes, that Theophrastus speaks of fossil ivory, both black and white: of bones, born in the earth; and of stones bearing the figure of bones. Ovid tells us,

> Vidi ego, quod fuerat quondam solidissima tellus,
> Esse fretum. Vidi factas ex æquore terras:
> Et procul à pelago conchæ jacuere marinæ;
> Et vetus inventa est in montibus anchora summis.
>
> *Metamorph. lib.* xv. *l.* 262.

Alexander *ab Alexandro*[*] says, he remembers to have seen in the mountains of Calabria, at a considerable distance from the sea, a variegated stone of a hard marble, in which many sea-shells, but little changed, were heaped, forming but one mass with the marble. He also relates, that Jovianus Pontanus informed him, that being once on the promontory of Pausilypus, near Naples, he saw in the middle of a piece of a stone, which was broken from the rock by the violence of the tempest, a wooden beam, surrounded on every side by stone, and grown into one body with the rock.

Tertullian also[†], anxiously endeavouring to prove, from natural appearances, that a general deluge had, according to scripture, taken place; dwells, particularly, on the discovery of the remains of marine animals on mountains, and on various parts of dry land, at a considerable distance from the sea.

For several succeeding ages, the writers of natural history were, at least, with respect to their account of these substances, little more than mere copyists of Pliny; who, although he had affixed names to these substances, descriptive of the forms they possessed, meant not thereby to give any opinion as to their origin.

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[*] Genialum Dierum, liber quintus, 1532.

[†] De Pallio, cap. ii. pag. 6. ed. Salmas.

In the thirteenth century, Albert le Grand* speaks of the branch of a tree being found, on which was a bird's nest; with birds contained in it, the whole being a mass of stone. The *vis formativa* of Aristotle was, however, sufficient to account, in the opinion of Albert, for this extraordinary phenomenon. But the opinions, which were entertained at this period, respecting these substances, were exceedingly incorrect. The doctrine of equivocal generation, which had been adopted by the disciples of Aristotle, contributed very much to mislead those who made these substances the subject of their enquiries; since, by also adopting the aid of certain occult qualities, their origin was supposed to be thus satisfactorily accounted for. Certain plastic powers were supposed to employ their influence in the earth, in creating substances, which bore the figure and resemblance of various vegetable and animal substances. To account for their formation, therefore, it was thought sufficient to refer to the hidden powers of the *vis plastica*, the *vis formativa*, and the *vis lapidificativa*.

In the sixteenth century, about the year 1517, the workmen employed in rebuilding the citadel of St. Felix, at Verona, discovered, that the rock, on which it was built, was full of petrified shells. This discovery excited the attention of the learned, to a very considerable degree; some attributing them to the active influence of the *vis formativa;* whilst others, perceiving their exact resemblance to real shells, declared, that they must be actual marine bodies thus enveloped in stone, by some accident. We learn, that when Fracastorius was asked his opinion respecting this phenomenon, he made for answer, that it had been attempted to be accounted for in three different ways. Some attributed it to the *vis plastica* and *formativa* of Aristotle: others supposed these substances to have been real marine bodies, deposited in these places at the time of a general deluge: whilst others had adopted that opinion, to which he himself was most inclined; that the parts, where these marine bodies were found, had formerly been covered with the sea, which gaining insensibly in some parts on the dry land, gradually changed its bed, leaving the positions it had formerly occupied for the cultivation and possession of man*.

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* Mineral. tract. I. lib. i.

In the sixteenth century, Agricola, to whose indefatigable spirit of enquiry, mineralogy is very much indebted, spoke much more explicitly of extraneous fossils than had hitherto been done. He particularly mentions the entrochi, and relates several instances of trees, and parts of trees, being found in a petrified state, at considerable depths in the earth †. But it is evident, that Agricola was not partial to enquiries respecting extraneous fossils; his attention was chiefly engaged in mineralogy, to the promotion of which his industry added very considerably.

In 1565, Conrad Gesner published, at Zurich, a work of great merit, *De Rerum Fossilium, Lapidum, et Gemmarum, Figuris.* About this time John Kentman, a German, collected a cabinet of petrifactions, which, considering the period in which it was formed, appears to have been very respectable. The catalogue of it is contained in Gesner's work. About the same time Valerius Cordus, a celebrated physician, undertook to publish a general oryctography of Germany; but does not appear to have received such encouragement, as would have warranted the prosecution of his plan.

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[*] Bonani Musæum Kircherianum, p. 198. Musæum Calceolarii et Musæum Com. Moscardi, p. 172.

[†] De Ortu et Causis Subterr. lib. iii. et De Natura Fossil. lib. vii.

Toward the close of this century, Bauhin formed a copious collection, and published the necessary descriptions of the petrified shells, which were found near the baths of Boll. This descriptive catalogue is to be found in his *Historia novi et admirabilis Fontis Balneique Bollensis, in Ducatu Wirtembergico. Montbeillard,* 1598.

About the same time Michael Mercatus wrote his *Metallotheca Vaticana,* which was not, however, published until the year 1717, when it was given to the public by Lancisius, physician to the pope. The opinions of Mercatus not differing from those which prevailed in the age he wrote, are not indeed very interesting; but the notes of Lancisius, and the figures, which are executed in a very masterly manner, and convey very accurate ideas of the bodies they represent, render the work of value.

In the seventeenth century, the collections of fossils became much more general. Only two catalogues of collections had hitherto appeared, but now several very extensive ones were published. In 1622, appeared a copious description of the celebrated museum of Calceolarius, of Verona; and twenty years after that was published the catalogue of Besler's collection. In 1652 appeared Wormius's catalogue; in 1663 was published Spener's, and in 1666 Septala's. An account of the museum of the king of Denmark was published in 1669; in 1674 Cottorp's catalogue appeared; and in 1678 was published that of the celebrated Kircher. In 1687 Dr. Grew wrote an account of the curiosities, which were contained in the museum of Gresham-College; and, in the year 1695, appeared the catalogue of Petiver, an apothecary, in London, who, at a vast expense, had formed a most valuable collection.

The earliest writer on these subjects, in this century, was Caspar Schwenkfeld, who, in 1600, published a catalogue of the fossils discovered in Silesia. But the most intelligent writer, of this period, was Fabius Columna, who published, in 1616, his treatise *De Glossopetris,* a work of considerable merit, intended to correct the erroneous opinions which had been entertained respecting these particular substances. In this century also, John Johnston, in the *Notitia Regni Mineralis, Lipsiæ*, 1661, described several petrified shells: he also particularly treats of the *Cornu Ammonis*, but evidently without supposing it to have been a shell. Numerous accounts were given respecting the astonishing properties which some of these figured stones possessed: and so fabulous and absurd were the greater part of them, that nothing but the darkness of the age could excuse the positive manner, in which they are related, and the firm belief which some appeared to have placed in them. One of these I will venture to introduce, leaving you to judge from that of the rest. It is related in *Historia Naturæ Joannis Eusebii Nierembergii. Antverpiæ*, 1635. pag. 430, cap. *De Lapide in Insulâ Monâ.*

"There is here a stone almost shaped like a human thigh, which possesses this wonderful property, that being carried away to any distance, it returns, of itself, the next night; as has been frequently found, by those who reside here. Hence it happened that Count Hugh, having heard of the power which this stone possessed, had it secured, by strong iron chains, to another stone, which was much larger than it, and cast at a considerable distance into the sea: but when morning dawned, to the wonder of the multitude, the stone was again found in its former situation. On this account, therefore, it was prohibited, by a public edict of the count's, that any one should again attempt its removal. But, it happened, on a time, our author informs us, that a certain countryman, for the sake of making a fair experiment, bound the stone to his thigh—directly the thigh became mortified, and the stone escaped, and returned to its former situation."——But to return to our sketch. To enumerate all the writers on oryctology of this period would be unnecessary; it will be sufficient to mention some of those authors, whose works deserve most particular attention.

Nic. Steno, in a dissertation, *De Solido intra Solidum Contento*, published in 1639, at Florence, displayed a considerable degree of sound judgment in his enquiries respecting these substances. The *Museum Metallicum* of the indefatigable and illustrious Aldrovandus, published in 1648, also contains the descriptions and delineation of several fossil bodies. The work of Augustino Scilla, *De Corporibus marinis lapidescentibus*, published at Naples in 1670, also contained a considerable portion of information, the result of most careful and anxious enquiry. About this period too, several learned men undertook to publish the oryctological history of several different parts of Germany, Italy, &c. Thus the fossils of Silesia were described by Caspar Schwenkfeld; those of Hildesheim by Frid. Lachmund, in 1669; and those of Switzerland, in 1680, by Jo. J. Wagner. About this time was also published a dissertation, by Jo. Dan. Geyer, at Frankfort, *De Montibus conchiferis et glossopetris Alzeyensibus*; and at Leipsic, a dissertation by Albertus, *De Figuris variarum Rerum in Lapidibus, et speciatim Fossilibus, Comitatus Mauffeldiæ*. Nor were the fossils of this country neglected; the *Lithophylacii Britannici Ichnographia* of Lhwyd, published at Oxford in 1669, contained a very ample catalogue of English fossils, contained in the Ashmolean Museum. In 1664 was published, by Thomas Lawrence, *Mercurialis Centralis*; or an Account of Subterraneal Cockle and other Shells in Norfolk. Several English fossils are also described in Doctor Plott's Natural History of Oxfordshire, published in 1686; as well as in that of Staffordshire, written by the same author. In the Natural History of Northamptonshire, by Dr. Morton, and in Dr. Leigh's Natural History of Cheshire, Lancashire, and of the Peak of Derbyshire, which were published nearly at this time, several curious particulars are recorded, relative to fossil bodies found in these parts. But the most important publications of this period, which related to these substances, were those of Dr. Woodward, particularly, the Natural

History of English Fossils. This valuable work contains a catalogue of that valuable collection of fossils which the Doctor had formed, and which is now in the possession of the University of Cambridge. Some notice is also taken of these substances in Christopher Merret's *Pinax Rerum naturalium Britannicorum,* the first part of which was published in 1667; at the same time Mons. Childrey published, at Paris, *L'Histoire des Singularites naturelles d'Angleterre, d'Europe, et du Pays de Galles,* in which several fossil substances are spoken of.

Rieske, Major, Kirchmajer, and Sachs, deserve also to be mentioned, for the aid they yielded to this science at this period. Several very valuable contributions also appeared, in different periodical publications, illustrating several parts of the science. Among those most worthy of attention, a dissertation of Wolfgang Wedel may be placed, with the utmost propriety. In this dissertation, *De Conchis saxatilibus,* which he introduced in 1672, in the Ephemerides published under his direction, he differed widely from his cotemporaries; and unreservedly asserted, that the stones, bearing the form of shells, were actual petrifactions; being natural shells converted into stone.

Among the last supporters of the opinions, of the generation of these bodies in the bowels of the earth, may be mentioned the celebrated Langius, who strenuously contended for their having thus obtained their forms and existence: Dr. Plott, who believed their figures to be the operation of certain plastic powers, with which certain saline bodies were endowed: and, lastly, Lhwyd, who combated the *vis plastica* of Plott, and supported the ideas of their production from the seminia of fishes, &c. raised with vapours from the sea; and conveyed by the clouds and rain, through the crevices into the internal parts of the earth. The more rational conjecture of Woodward, who attributed their situation to the effects of the general deluge, was rendered of less effect, in opposing these notions, from his having attributed to the waters of the deluge, an almost universal solvent power; by which he supposed the rocks and mountains were melted down, and thus allowed the admission of these substances into their external parts: not considering that, by the same power, these bodies would themselves have been reduced to a mass, not bearing their proper figures.

Nothing, perhaps, contributed so much towards diffusing a proper idea respecting the origin of these substances, as the *Historia Animalium Angliæ* which contained some excellent remarks, *De Lapidibus ejusdem Insulæ ad Cochlearum quandam Imaginem figuratis. Lond.* 1678; and the *Historia seu Synopsis methodica Conchyliorum*, 1685, all written by Dr. Lister. By these publications the student was enabled to form a comparison, between the original shell, and the similar shell in a fossil state; since, in several instances, the Doctor had displayed in his plates, the same shell in both states. How much this must have contributed to producing a just judgment, of the real nature and origin of these substances, must be obvious; and to this circumstance, perhaps, we ought in part to attribute the change of opinion, which very generally took place at this period. Still, however, the science was involved in that cloud, which had so long obscured it. The *vis plastica*, the *vis formativa*, and the sportive creations of nature, were terms yet in frequent use. Those who were more than half convinced, but had not quite shaken off the influence of a long adopted opinion; as well as those who, though quite convinced, had not the courage to acknowledge having been in error; spoke of these bodies in the indefinite language of *lapides figurati*, *lapides idiomorphi*, *lapides qui figuram habent conchæ*, *cochleæ*, *&c.* Some indeed would venture to term them *conchæ lapideæ*, *ostrea lapidea*, *&c.* carefully avoiding to speak of their origin, or to admit them to be bodies, changed from their original animal state to that of stone.

Careful investigation, however, having now rendered it manifest, that these substances were neither the productions of chance, nor the creatures of these imaginary capricious powers, they excited more general attention: being better understood, they became more capable of systematic arrangements, and the study of them embraced more of science.

The eighteenth century, therefore, commenced under the most favourable circumstances for this science. The learned and industrious Scheuchzer, who had adopted the most rational theory respecting the origin of these substances, published, in 1702, his *Lithographia Helvetica Curiosa*; which was followed by his *Piscium Querelæ et Vindiciæ*, in 1708; with his *Herbarium Diluvianum*, in 1713; and his *Musæum Diluvianum*, in 1716. Mylius, Bajer and others, also, about this time, published the oryctological discoveries which had been made in the several parts in which they resided, or which they had explored. Among these writers, none deserves more particular mention, than the accurate and diligent Rosinus; whose examination of the encrinus may be regarded as a model by which all similar enquiries should be directed. His projected works promised very considerable addition to the knowledge of fossils; but these were suppressed by his premature death. Bruckman also pursued this kind of enquiry, with the utmost assiduity and success; which is rendered evident by his work, *de Lapide Nummali Transylvaniæ;* as well as, by the numerous observations to be found, in his epistolary accounts of what he had discovered, worthy of notice, in his various travels. The works of Ritter, which were published also about this time, contain much oryctological information. Indeed the science, now rendered respectable, by being divested of the numerous absurdities, with which ignorance and false philosophy had loaded it, was assiduously cultivated by many learned and ingenious men; and became more and more interesting, from the numerous objects of astonishment it displayed. Linck, Jacobus a Melle, Harenberg, Ehrhart, Volckman, Klein, Donati, Reaumur, with many other men of learning, aided the progress of the science by their well directed labour.

One work, published in 1726, deserves to be particularly noticed; since it plainly demonstrates, that learning may not be sufficient to prevent an unsuspecting man, from becoming the dupe of excessive credulity. It is worthy of being mentioned, on another account: the quantity of censure and ridicule, to which its author was exposed, served, not only to render his cotemporaries less liable to imposition; but also more cautious in indulging in unsupported hypotheses. The work is intitled *Lithographiæ Wirceburgensis Specimen Primum*, and was written by Dr. John Bartholomew Adam Beringer. We are here presented with the representation of stones, said to bear petrifactions of birds; some with spread, others with closed, wings: bees and wasps, both resting in their curiously constructed cells, and in the act of sipping honey from expanded flowers: spiders weaving their webs: moths and butterflies engendering: and, to complete the absurdity, petrifactions representing the sun, moon, stars, and comets: with many others too monstrous and ridiculous to deserve even mention. These stones, artfully prepared, had been intentionally deposited in a mountain, which he was in the habit of exploring, purposely to dupe the enthusiastic collector. Unfortunately, the silly and cruel trick succeeded so far, as to occasion to him, who was the subject of it, so great a degree of mortification, as, it is said, shortened his days.

In the middle of the eighteenth century, a more strict and close mode of philosophising, than had been hitherto employed, appears to have been generally adopted: this is evident in almost all the writings which were published on these subjects at this period. Correctness of judgment, and propriety in arrangement, became now generally conspicuous. This we can, without the least hesitation, attribute, in a great measure, to the advantages which this science derived, with mineralogy, from the well directed labours of those, who strove to place the different productions of nature under appropriate classes. On this account, much is undoubtedly due to the scientific exertions of Linnæus and of Wallerius: both of these writers, in their different systems of arrangement, having taken a very comprehensive view of the objects of our enquiry. The oryctology of D'Argenville is replete with information, which must be highly acceptable to the admirer of lithology. Gesner's (Jo.) dissertation *De Petrificatis*, published in 1758, is highly valuable, as a faithful and neat compendium of the science. The *Traité des Petrifactions* of Bourguet is a work still more useful; from its uniting with accurate description, the illustration of faithful plates, and the advantage of a convenient arrangement. But the work, which comprises the most information, and indeed, from which every lover of the science must derive the greatest degree of satisfaction and pleasure, is that of the celebrated Mr. Knorr, published in Germany, entitled, *Recueil des Monumens des Catastrophes qui la Globe de la Terre a essuiées.* This magnificent work, contained in three folio volumes, and adorned with elegant coloured representations of different specimens, was began by the learned G. W. Knorr, and at his death was continued with equal care and zeal by Mr. Walch.

The only works, entirely devoted to these subjects, which have appeared in England since the republication of Lhwyd's work, are, Descriptions and Plates of Petrifactions found near Bath, by John Walcott; and Gustavus Brander's *Fossilia Hautoniensia, in Musæo Britannico deposita;* the scientific descriptions of which were written by Dr. Solander. Through the whole series of the Philosophical Transactions of the Royal Society of London, is dispersed a considerable portion of information respecting the remains of the ancient world, in communications from Sir Hans Sloane, the Hon. Daines Barrington, Dr. Stukeley, Dr. Molyneux, Dr. Mortimer, Dr. Camper, Dr. Hunter, Mr. Ray, Mr. Joshua Platt, Mr. Da Costa, Mr. John Hunter, and many other gentlemen distinguished for their avidity of research, and their extensive knowledge respecting the astonishing productions of nature. The *Academiæ Scientiarum Imperialis Petropolitanæ Commentarii* contain some very excellent papers on these subjects, by Professor Pallas.—The *Societatis Regiæ Scientiarum Gottingensis Commentarii*, the *Memoires de l'Academie Royale des Sciences*, also contain several very instructive papers. In the Transactions of the American Philosophical Society, some interesting papers have lately appeared, by Thomas Jefferson, Esq. Dr. Wistar, and Mr. Turner, respecting the bones of various unknown animals, which have been discovered in that part of the world.

In 1781 were published some very interesting observations on these subjects, in the Physiological Disquisitions of Mr. William Jones.

In 1793 was published, by Mr. Martin, of Buxton, Figures and Descriptions of Petrifactions collected in Derbyshire. Of this work only seven numbers have been yet published. The figures are given with such fidelity, and the descriptions with so much accuracy, that it is only by supposing the natural history of these substances is not so generally known, as to have excited a sufficient degree of interest in collectors, that we can account for the public demand not having called for their more frequent publication.

Cuvier, in a paper given into *La Societé d'Histoire Naturelle*, at Paris, has published some important remarks on the fossil remains of various unknown animals; and has likewise announced his intention of publishing his enquiries on this subject, on a very extended scale. From this work so much information is to be expected, that, I doubt not, its publication will prove an important epoch in the history of this science.

It must, however, be acknowledged, that during the last fifty years, trations of Mr. Donovan, the scientific publications of Dr. Shaw; and the ingenious lectures on Comparative Anatomy by Mr. Macartney: not to particularise the numerous interesting observations of Mr. Home, Mr. Corse, and various other ardent admirers of natural history. The science then, the study of which is here intended to be promoted, and which not only deserves to be considered as supplementary to zoology and mineralogy; but as the medium by which the one may be connected with the other, cannot surely but participate in the attention they obtain.

LETTER IV.

OPINIONS RESPECTING THE ORIGIN OF THESE BODIES....PLASTIC POWER....TRANSLATION OF SEMINAL PRINCIPLES....GROWTH OF STONES....TERMS....FIGURED STONES....DILUVIAN STONES....FOSSILS, EXTRANEOUS OR ADVENTITIOUS....NEW TERMS PROPOSED ....SECONDARY FOSSILS, VEGETABLE OR ANIMAL....*FOSSILIA* VULGO *DICTA*....IMPRESSIONS.....CASTS....FIGURED STONES.

To stumble at the very threshold, is, I acknowledge, rather ungraceful, and not very promising; but remember, that sometimes, the blame may lay in the stumbling block, and not in the man. This, I trust, will prove to be the case, in the present instance. I have to speak of substances, which, in my opinion, have never yet been designated by appropriate terms: and to treat of a science, which has not yet acquired a peculiar name.

to be proofs of this species of vegetation; since their volume was observed evidently to encrease, and apparently in determined forms.

From the total ignorance which subsisted respecting these substances, all the earlier writers contented themselves with employing words to describe them, which denoted their resemblance to certain forms; describing them, generally, as FIGURED STONES *(lapides figurati & lapides idiomorphi)*. Others, who supposed they owed their forms to certain extraordinary changes, which took place at the period at which the earth was overwhelmed by the general deluge, described them as DILUVIAN STONES *(lapides diluviani)*. But whilst they thus, with the utmost propriety, employed such expressions as were, at least, not likely to mislead, they, of necessity, were confined to such as were deficient in significancy.

But when the discovery was made, that most of these figured stones were remains of subjects of the vegetable and animal kingdom, these modes of expression were found insufficient; and, whilst endeavouring to find appropriate terms, a considerable difficulty arose; language not possessing a sign to represent that idea, which the mind of man had not till now conceived. The nature and origin of these substances had long been enveloped in the darkest ignorance; and when sufficient rays of light had broken in upon them, to enable the philosopher to view them more distinctly, he plainly saw the important relation, which they bore to the history of our globe; and found himself engaged, in the contemplation of objects almost unknown; and in the study of a science, entirely new. This occurring, at so late a period, when language was fully established, and when every word had its peculiar office allotted to it; necessity drove him to the alternative of either, coining new words, or of selecting, from those already in use, such as might be adopted for the description of these substances. The latter mode was preferred; and the word *fossil*, which had hitherto been appropriated to the whole of that class of bodies, which had been *dug* out of the consisted. It, therefore, can be employed to describe only that particular variety of the species, to which it actually belongs.

The word FOSSIL appears to be the only word our language can supply, which is capable of being employed as the term denoting these substances in general. The propriety of adopting it will appear, when we consider its derivation, and the characteristics of the bodies it is intended to signify. In the contemplation of these bodies, three circumstances offer themselves for our particular notice: first, their having been dug out of the earth; secondly, their original mode of existence; and, thirdly, the nature of the change which they have undergone. The term fossil, if its meaning be assumed, strictly from its derivation, must be acknowledged to mean, any mineral substance dug out of the earth; but, when it is recollected, that these bodies, in general, exhibit, to the senses, the most obvious marks of their origin, and of the changes they have undergone, it was sufficient for the common purposes of speech, that the word selected for them should express their other grand characteristic—their being dug out of the earth. But, although, when the body is itself present, and manifests to the senses, that, for instance, it was once wood, but is now flint, the applying to it the term fossil entirely completes the idea; yet this is not sufficient, in written language, where the senses cannot thus supply, that which is deficient in the term. Here appropriate epithets must be added, expressive of those parts of the idea, which are not already expressed. The epithets extraneous or adventitious, proposed by Sir John Hill, and generally adopted to the present time, are, in my opinion, objectionable; not only because they do not comprise the two circumstances, which are required to be expressed; but also because they convey opinions respecting these substances, which a closer examination will show are ill founded.

The term extraneous denotes, that the substance spoken of, is be natives of, and to have existed primitively in, the subterranean regions: such are the metals, stones of the granitic class, and most of the various substances, of which the primitive mountains are formed. Under the SECONDARY FOSSILS*, I place those substances, which bear indisputable testimony, in their structure and form, of their having existed in an organized state; and which are therefore known to have had an animal or vegetable origin; but which have afterwards entered into, and become, subjects of the mineral kingdom.

SECONDARY FOSSILS, which are alone intended to be the subjects of our investigation, may, according to their origin, be divided into two classes, VEGETABLE OR ANIMAL FOSSILS. Each class will be found also capable of a further division, into orders, genera, and species; which classification, although impossible to be made correspondent with that of their recent analogues, will certainly, however, yield some degree of perspicuity to the observations offered in this work. The varieties of the species can seldom be expected to be discoverable in our specimens; this term, therefore, may be adopted for those varieties dependent on composition; and which may be distinguished by the epithets, appropriated to the several kinds of matter of which they are formed: such as siliceous, calcareous, aluminous, bituminous, &c. Thus, I hope, without adopting any harsh or offensive change, all confusion of terms may be avoided, and an intelligible mode of expression secured

It is proper to observe here, that I shall consider as fossil bodies, some substances, which, by writers of considerable authority, have been deemed unfit to come under that denomination. The substances which I here allude to, are those which, having lost, by the decomposing powers of certain subterranean processes, not only all the softer parts, but almost the whole of those principles which are peculiar to animal or vegetable substances, seem to retain only the

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* Transubstantiata, Linnæi.

Besides the bodies already mentioned, we shall have, occasionally, to notice certain FIGURED STONES *, which, independent of the interference of any animal or vegetable body, present the resemblance of some body, not of the mineral kingdom. When this is the result of the fortuitous concurrence of certain marks on the surface, they have been termed *lapides picti*, and *graptolithi;* and when the resemblance depends on the whole external form, they have been named *lithoglyphi.*

Should our old friend Wilton complain of this letter being too dry and unentertaining, remind him, that unless our terms are defined, there never can be a hope of our obtaining a good understanding. Promise him, that our pursuits shall yield him a large stock of entertainment, with a full share of the marvellous. Assure him, that he shall hear

> ——————Of antres vast, and deserts idle,
> Rough quarries, rocks, and hills, whose heads touch heaven. *Shakspeare.*

Tell him, I hope his faith will be comprehensive enough to enable him to receive, with full credit, the accounts delivered by Baptista Fulgosus, Ludovicus Moscardus, and Theodorus Moretus, that a whole ship, with its anchors, broken masts, and forty mariners, with their merchandize, were found, in the year 1460, in a mine fifty fathom deep, in the neighbourhood of Berne, in Switzerland †. Relate to him, that Valchius, in his Commentary on the *Klein Baur*, tells us of a truly curious fossil man, found at Maria Kirch, near Strasburgh, by a miner, who, breaking open the hollow of a rock, was astonished at beholding the figure of an armed man, standing upright, now composed of a mass of silver, of five hundred pounds weight. If his interest and astonishment be not hereby sufficiently

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* Lapides figurati—Lithomorphi, Wallerii.

† Musco di Ludov. Moscardo. lib. ii. cap. 3. Theodor. Moreti, tract. de Æstr. Maris, cap. 21. Baptist. Fulgosi Dict. & Fact. Mem. Collect. lib. i. cap. 6.

The globe which we inhabit, presents, every where, a surface, more or less irregular. In some places, gentle risings and declivities only are found: in others, the elevations are vast and lofty; and are accompanied by proportionate vallies. In some parts, the dry land, interrupted only by slight intersections, for the currents of rivers, stretch into immense continental tracts: whilst in others, prodigious excavations, in the substance of the earth, serve as the receptacles of immense oceans of water. These, it is allowed, exceed, in the sum of their extent, that of the dry land; and bear a very near proportion, in their depth, to the height of the loftiest mountains.

Mountains are, with propriety, divided into primitive, or primeval; and secondary, or epizootic. The primitive and secondary mountains differ, not only in their composition, but even their form.

The primitive mountains are composed of granites, and of stones of the granitic class; of porphyry, jasper, serpentine, sand-stone, trap, and sometimes, but more rarely, of lime-stone, fluors, gypsum, &c. These substances, sometimes, lay in strata; but, most frequently, they are found in huge blocks; thus a granite mountain, about thirty miles from the Cape of Good Hope, called the PEARL DIAMOND, rises out of the ground, to the height of about 400 feet, being half a mile in circumference; and formed of a single block of granite. These mountains never cover secondary mountains, but are often covered by them. They are commonly the highest ridges in any chain, and terminate, generally, more narrow and sharp, than the secondary.

The most distinguishing character of these mountains, according to Mr. Kirwan, is a circumstance which particularly demands your attention—no organic remains, he says, are to be found, in the interior part of the substance of the stones of which they are composed.

the finer gravel; which likewise varies, in different parts, in its degree of fineness, and in its colour. Underneath these are the infinitely varying strata of sand-stone, lime-stone, &c. which serve, with the trunks of trees, which have grown in, and which have been nourished by, the first layer; and with the bricks and tiles, made from the second layer, to supply the materials, of which the dwellings of man may be composed. They also serve, with the sand and gravel of the third stratum, to supply that kind of surface to the earth, in those parts which are most inhabited by the civilized part of mankind, as may best contribute to the comfort and expedition of the intercourse, which must, necessarily, take place between the inhabitants of distant parts. These strata of stone, varying perpetually in their colour, solidity, and texture, form, in some places, the ceilings and floors of the vast subterranean caverns, which are found in various parts of the world; and which often contain, as do those, particularly, in the principality of Bayreuth, and in the Hercynian forests, very interesting specimens of those remains, which are the objects of our particular research. They also form the surrounding parts of those mines, which contain the valuable metals, which civilized man forms into innumerable articles of utility, and of ornament. Beneath schistose or slaty strata, are, generally, found the immense beds of coal, so necessary to the comfort, and, in some situations, even to the existence of man. These strata do not always follow each other in regular order; since sand and gravel are, sometimes, found at a considerable depth, and trap, or rag-stone, is often interposed between them, in various directions.

In almost all these strata, even to a very considerable depth, the remains of vegetables and animals, which have existed in former remote periods, are frequently found: and, in general, possess the same physical and chemical properties, and are composed of similar constituent parts, with the strata themselves. What these tuent of the pebbles and sand, which form the third stratum I have mentioned. It is difficultly acted on by any acid, except that which is obtained by distillation from Derbyshire fluor spar; and which is termed fluoric acid. It is, however, very powerfully acted on by the alkalies, which promote its fusion: and, when thus combined with it, in a certain degree, form glass. It is this earth, which chiefly forms the common *flint*, and *horn-stone;* the more pure *chalcedony;* and the still purer *quartz*, or *rock crystal;* the variously figured *agate;* the arborised *mochoa;* the beautifully marbled *jasper;* the sportive *Egyptian pebble;* and the finely veined *woodstone*, still retaining the mark of every fibre, which regulated its pristine structure. Combined with a certain portion of alumine, it forms the chief constituent of the *amethyst*, *topaz*, and various other stones, which, from their brilliancy, hardness, and colour, are estimated as gems. This earth, also, chiefly helps to constitute the *granite*, of which the primitive mountains are formed. This stone frequently displays, in a most beautiful and distinct manner, the three substances of which it is composed. The *feldspar*, the constituents of which are silica, alumine, and magnesia, will be seen, generally, in oblong, curd-like masses, of various sizes. The *mica*, composed of the same constituents, but in different proportions, will appear generally in grains, about the size of a pin's head, of different colours, but, most commonly, black; and, sometimes, in white flakes of a metallic lustre. The quartz will be found interposed between these, generally of a greyish colour; and appearing to be the medium by which the other two substances are agglutinated together.

LIME is the earth which chiefly forms the various lime-stones, which are placed, in different layers, beneath the beds of clay and sand. This earth is rendered tolerably pure, when, by intense heat, it is made into *quick-lime*. It fuses, when combined with flint and clay; and readily combines with acids. It is soluble in 700 times

With the phosphoric acid, an acid originating in the animal kingdom, lime also frequently combines, to form *phosphate of lime.* By this combination, is also formed *phosphorite,* a stone found in large masses, chiefly in Spain and in Germany.

Lime has been supposed by those of high authority, to have been entirely of animal origin. This, however, cannot be admitted; although it is indubitable, that a considerable portion of it has passed through the animal kingdom: vast masses existing of animal remains, resolved into this earth, which still retain sufficient of their previous structure, to point out the form they had originally borne.

MAGNESIA is a very light substance, and soluble in about 2000 times its weight of water. The various stones, in which magnesia predominates, almost always shew its presence, by a smooth and unctuous feel; this is particularly the case with the various *steatites,* or *soap-stones.* They also sometimes manifest a flaky structure, as is the case with *common talc.* Sometimes they display a striated texture, with a lustre of the silky kind, as in the *amianthus,* and in the *asbestos;* the stone, from which may be made incombustible cloth. *Serpentine,* a stone which, from the disposition of its colours, is supposed somewhat to resemble the skin of a serpent; and which has rather a soft, and somewhat of a greasy feel, with a silky lustre, is composed of this earth, with a certain quantity of silica, and a very small portion of iron.

SULPHURETS OF METALS, and particularly that of iron, found at various depths, and frequently entering into the composition of secondary fossils, demand a few words. These are the substances more commonly known by the name of *pyrites,* or *marcasites,* and are formed by the intimate union of sulphur with some of the metals. They, in general, shine with a brilliant metallic lustre: and when they do not, they frequently suffer decomposition, on exposure to the action of the air.

particularly of one, rather larger than the rest; the external ornaments of which, as well as the fanciful disposition of the garden, which almost surrounded it, manifested the superior taste of its possessor, and induced us to quit the chaise to have a nearer view of this charming spot.

We had not long alighted, before a gentlewoman, about forty years of age, of a genteel and pleasing appearance, who was at the window when the carriage stopped, advanced to us from the house, which had most particularly excited our attention; and, in the most polite manner, requested us to favour her with our company, and to partake of some refreshment. The invitation was too welcome to us to be rejected; we, therefore, cheerfully accompanied her into the house; the inside of which manifested the same neatness, and the same display of taste, which we had already witnessed. Shewing us into a parlour, she in a very frank manner informed us, that we were now in the vicarage house, pointing to the church, at about half a mile distance; and informed us, that her husband had performed the duties of this cure, nearly ten years.

This information, so well calculated to give us confidence in our new acquaintance, demanded a similar frankness on our part. We therefore stated who we were; and that a wish to contemplate the various beauties of nature's works, had chiefly incited us to this journey. Mutual confidence being thus established, our kind hostess informed us, that, as the sun would soon set, and as there was no inn which could receive us, within fifteen miles, she must intreat our promise to take up our abode there that evening. This, she said, was a request, in which Mr. Inman would most heartily join her; nay, she added, he would not forgive her if she had failed, in securing him the pleasure of such agreeable society.

The tea-things were soon arranged, and our kind hostess placed us in the bow-window, from which we were gratified, with an uninterrupted view of a very extensive plain of country; stretching from the unexpected weight of the parcel committed to his charge, nearly let it fall to the ground.

When he had a little recovered himself, he requested Mr. Inman to inform him, what kind of substance this was. "It is," said Mr. Inman, "a species of fossil wood, which we, sometimes, find on digging in different parts of this mountain." "Wood!" exclaimed Winton, turning round, and depositing the parcel in my hands for my examination, "why really it is as hard and heavy as any stone I ever felt!" "By fossil wood," said Mr. Inman, "I mean that which was once wood, but which is now become stone." A closer examination now shewed me, that this substance was more truly curious, than it had even appeared to be on a superficial view; since I discovered, that its resemblance to wood consisted, not merely in its general external appearance, but that this similitude was discoverable, in its internal structure: the knots, the concentric lamina, and even the smallest fibres of the wood, being perceptible. Perceiving our attention to be so much engrossed by this curious substance, which appeared to us of such an ambiguous nature, Mr. Inman remarked, that as the evening was too far advanced to allow any excursion on the mountain, he would endeavour to amuse us with a little cabinet, containing some curious smaller specimens of a similar kind; some of which he had acquired, during his travels on the continent. We soon surrounded the table, on which he, in turn, placed several drawers, containing a considerable number of beautiful and interesting specimens, of what, according to the suggestions in your obliging letters of instruction, we should name, vegetable fossils. Not only did I never before view a collection so interesting; but I never had even conceived that there could exist in bodies of this kind, so much beauty; or that substances, indubitably of a mineral nature, could possess, so distinctly, the characteristic forms of vegetables.

One specimen, which, as it lay in the drawer, was not to be distinguished from a well smoothed piece of common deal, possessed so great a degree of hardness, that on being struck against a piece of steel, sparks were produced, exceeding in number and brilliancy, those which proceed from ordinary gun-flint. Another piece possessed the blackness of ebony, but had as high a degree of polish, as the smoothest glass. Another specimen was almost entirely invested with a crust of most brilliant crystals. Another——but I must not pretend to describe the various beautiful and astonishing objects I beheld. So great was the variety which passed before my eyes, and so much was my mind engaged in forming fruitless conjectures, respecting the ambiguous nature of these wonderful bodies, that my recollection of them is rendered confused, and my total ignorance respecting them, prevents my possessing appropriate words to form their description.

I was mortified to find that Mr. Inman, himself, was not able to furnish me with any real information respecting them: he merely stated it to be his opinion, that they had been buried ever since the days of Noah; and had, by the great length of continuance under ground, suffered this surprising change.

On a subject so exceedingly interesting, the mind, not satisfied with vague conjecture, seeks for somewhat like explicit information; or is, at least, anxious to ascertain, how far investigation has been successfully employed, on such questions as may tend to explain, how vegetables could thus be converted into the hardest stone; or by what means they could be preserved, during so long a period, as that which must have existed, between the time of their commitment to the earth and of their transmutation.

On the following morning, our kind host conducted us up the mountain; and shewed us the spot where, on the day before, he had found the pieces of wood we had seen. We, therefore, eagerly set to work, here, with a small mattock, which he had purposely provided, and were so fortunate as to find two or three good specimens, which, I assure you, we carefully preserve, purposing to add them to your collection; but on this condition, that, in your next letters, you favour us with some information, respecting these wonderful bodies, which have actually passed, from the vegetable to the mineral kingdom.

Yours, &c.

LETTER VII.

VEGETABLE FOSSILS....FOSSIL TREES....DESCRIBED BY THE ANCIENTS....BY THE MODERNS....FOUND IN ALMOST EVERY PART OF THE WORLD.

It has been my endeavour, in my preceding letters, to furnish you with some general and useful notions, respecting secondary fossils in general; as well as with some general account of those substances, which will be found most frequently concerned, in those important changes which secondary fossils have undergone.

Vegetable fossils, or vegetable secondary fossils, will now, very properly, according to the arrangement I have adopted, become the subjects of our investigation. This also will be the proper moment for their consideration; since the curious phenomena you lately beheld, have, it is very evident, excited your curiosity and interest, respecting their particular changes, to a very considerable degree.

Vegetable fossils *, I shall divide into the following orders:—

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* Phytolithi, of Linnæus and Wallerius.

1. **Fossil trees**[*].—2. **Fossil plants**[†].—3. **Fossil roots**[‡].—4. **Fossil stalks**[‖].—5. **Fossil leaves**[§].—6. **Fossil fruits and seed-vessels**[¶].

With respect to **fossil trees**, as well as with respect to every other fossil of which I shall treat, I shall adopt that which appears to be the mode best adapted to excite your interest, and to secure to you every necessary information. I shall endeavour to supply you with an historical sketch of what has been, hitherto, made known respecting them; to state the several theories by which it has been proposed to account for their origin; and lastly, to lay before you the facts, which later observations have discovered, and the opinions which these appear to warrant.

That the existence of fossil trees was known, in very remote periods, there cannot exist the least doubt; but no rational opinion, respecting their nature or origin, has been offered until modern times. Theophrastus[**] speaks of a stone, bearing, in its external appearance, a resemblance to rotten wood. Strabo[††] relates that trees, much resembling the laurel and the olive, were buried in almost the whole of the mouth of the Red Sea; which, during the ebb, were sometimes exposed, and which, during the flowing in of the tide, were sometimes torn up. This, he observes, is very astonishing; since, even higher up in the country, no trees are to be found. Eratosthenes relates the same circumstance, as observable in the Persian Sea. Pausanias[‡‡] mentions a fossil wood, which was considered as fossil ebony. Referring to a certain statue formed of ebony, he says, he heard from a man of Cyprus, exceedingly learned in the properties of plants, that ebony never put forth either leaves or fruits, nor ever shewed a trunk above ground. Agricola *, also, notices this supposed particularity of ebony, adding, that its external appearance is similar to that of jet; from which, however, it differs in being but little affected, whilst jet burns, and is consumed, in the fire. A piece of this kind of ebony, he says, was once presented to him as a branch of black coral.

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[*] Phytolithi Arborum, of Linnæus; Lithoxyla, of Wallerius; and Stelechites and Dendrolithes, of others.

[†] Phytolithi Plantarum, of Linnæus; and Plantæ petrificatæ, of Wallerius.

[‡] Rhizolithi, of Wallerius. [‖] Lithocalami, of Wallerius.

[§] Lithophylla, of Wallerius; and Lithobyblia, of others.

[¶] Carpolithi, of Wallerius; and Spermolithi, of others.

[**] Theophrast. ΠΕΡΙ ΤΩΝ ΛΙΘΩΝ. sect. xxix. [††] Strabon. Geograph. lib. xvi.

[‡‡] Pausanias, Græciæ Descriptio, lib. i. cap. 43.

There is, perhaps, no part of the known world, in which the mineralized remains of trees have not been discovered. According to Agricola †, very large trunks of firs have been dug up in different parts of Germany, turned, with their bark, into stone; the crevices of which were filled with golden coloured pyrites, and marcasites. Similar trees, with branches, have also been dug up near Cracow, which, when cut into the form of whetstones, were sent as presents by the barons, who held the territory, to Ferdinand the king of Bohemia. He relates, that he himself saw, in a pool near the castle of Robestein, in Misena, many trunks of trees, which were changed into stone. In the earth from which the alum is obtained, near Hildesheim, oak trees were found converted to stone; and in the same country, near to the castle of Mariaburgh, he mentions a hill full of logs in a petrified state. These are very long, and seem as if they had been placed together in heaps; their stony hardness being rendered sufficiently evident, on being struck by a piece of iron, or another stone. In the aluminous earth of Hildesheim is also found the fossil wood, which, as has been just observed, has been considered as fossil ebony.

Agricola, whose actual researches were such as must have furnished him with numerous opportunities of determining, that this astonishing change of wood into stone did actually take place; but,

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* Agricola, De Natura Fossilium, lib. viii. p. 324. Basileæ, MDLVIII. † Loc. cit.

at the same time, being influenced by the predominant opinion of that period, that nature amused herself by modelling, in stone, imitations of the forms of organic bodies, he thus endeavours to furnish a mode of distinguishing in which of these classes, the stony substances bearing a vegetable form, are to be arranged. As nature, he says, generates stones, resembling trees, it must be diligently observed whether they possess the bark, pith, &c. since if these are not discoverable, it may be concluded, that they are not trunks of trees converted to stone, but that nature has formed those stones, to resemble the trunks of trees. Thus he says, respecting the piece of timber found by Jovianus Pontanus, in the promontory of Pausilypus, in consequence of a part of the rock being broken off by the violence of the storm, we cannot determine, as these particulars are not explained, whether it was a stone which only bore the form of a piece of wood, or whether it was actually wood, converted into stone.

Thus also Kircher, speaking of petrified woods*, observes, there are some which formerly have been wood, and have been converted into stone by the long course of time, or by the influence of the lapidific power. Others there are, which cannot be said to derive their origin from a vegetable nature; except in some very remote way, but are entirely the work of nature.

De Boot† relates, that near Bruges, in Flanders, upon digging to the depth even of 50 feet, whole forests were found; the leaves, and the trunks being so little altered, that the different species of the trees might be ascertained; and even the different series of leaves, which had fallen yearly, might also be distinguished. Schoockius also observes, that large trunks of fossil trees are dug up in different parts of Germany; particularly in Poland, near Bois-le-duc, in the province of Brabant; and, according to Olaus Wormius[*], they have even been found in the loftiest and most craggy mountains of Iceland, and in almost all the maritime parts of Holland, Friesland, Zealand, &c. Subterranean trees have also been found by Franciscus Stellutus, not enveloped merely in earth, but in stone. In Misnia, a beech tree, with all its leaves and branches, was found in a stony stratum, a hundred and eighty ells deep. In the valley of St. Joachim, at a considerable depth, was found an oak, with its roots and branches, in a petrified state, according to Leibnitz[†]. Both Gesner and Albinus mention a beech having been found, which was afterwards formed into whetstones. Leibnitz also mentions a stone, which was in the possession of Benjamin Olitsch, an ingenious miner; and which he had procured from Augustoburgh, in Misnia, which would be directly known to have been part of an alder.

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* De Natura Fossilium, lib. vii. p. 324. Basil. MDLVIII. Kircheri Mund. Subt. lib. viii. cap. 6.

† Gemmarum & Lapidum Historia, lib. ii. cap. 158.

Buffon relates, on the authority of Rammazini, that for four miles round the town of Modena, wherever the earth is dug to the depth of 63 feet, if the workmen pierce about five feet farther, with a boring instrument, the water rushes up with such impetuosity, that it fills the wells to the top, almost instantaneously. The water in these wells continues perpetually; and is neither augmented nor diminished, by rains or drought. It is still more remarkable, that on this spot, whenever the workmen dig to the depth of 14 feet, they find the rubbish and ruins of an ancient city, paved streets, houses, and different pieces of Mosaic work. Below this, the earth is solid, and appears not to have been moved. Still lower, they find a moist soil, mixed with vegetables; and at the depth of 26 feet, entire trees, as filberds, with nuts upon them, and great quantities of branches and leaves. At 28 feet, there is a stratum of soft chalk, 11 feet thick, mixed with sea shells; and after this they again meet with vegetables, leaves, and branches of trees, till they arrive at the depth of sixty-three feet; where there is a stratum of sand, mixed with gravel and shells, similar to those which appear on the coasts of Italy. These successive strata lie always in the same order, wherever pits have been dug; and, sometimes, the boring instruments fall in with trunks of large trees, which the workmen pierce with great labour: they likewise meet with bones of animals, pit-coal, flints, and pieces of iron. Ramazzini, who relates these facts, thinks, that the Gulf of Venice formerly extended beyond Modena; and that this land, in the progress of time, has been gradually formed by the rivers, assisted, perhaps, by inundations of the sea *.

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[*] Lib. ii. cap. 15. [†] Leibnitii Protogæa. Gotting. sect. xlv.

In the Isle of Anglesey, subterranean trees are frequently dug up; and in the Isle of Man is a marsh, called Curragh, six miles long, and about three broad, in which subterranean fir trees, in vast quantities, are found: and though eighteen or twenty feet below the surface, they appear as if standing firm on their roots.

Subterranean trees are found in various parts of Ireland, particularly in the morasses; but the greatest attention has been excited to the wood, actually in a petrified state, which is found in the neighbourhood of Lough Neagh.

Dr. Boates, in his account of Lough Neagh †, relates, that on the borders of that lough are found little stones, of a pretty moderate length; some of them round in their compass; others flat, or flattish; and some angulous: and which being looked on, as well near, as from afar off, seem to be nothing else but wood; and by every one are taken for such, until one come to touch or handle them: for then, by their coldness, hardness, and weight, it appeareth that they are not wood, but stone. But with respect to wood, placed in the lake, being turned by its water into stone, he says, he had never

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* Buffon's Natural History, vol. i. p. 481.

† The Natural History of Ireland, by Dr. Gerard Boate, published by Hartlib, in 1652, and republished in 1755.

been able to learn the fact, from any persons who had themselves tried this matter; but several affirmed, that it had been done by others of their acquaintance.

Mr. Wm. Molyneux, secretary to the society of Dublin, for promoting researches in natural philosophy, believed in the petrifying power of Lough Neagh, in opposition to those who asserted, that the petrified wood is found in the sand hills near the lough. He also thought this power was chiefly exerted on the holly; but he never obtained any positive proof, of this property existing in the waters of the lough; nor could he procure a piece of petrified wood, with unchanged wood adhering to it. He observes, that when briskly calcined, the ashes of this petrified wood were affected by the magnet*.

But Mr. W. Smith, whose opportunities of observation were frequent, says, in answer to some queries proposed to him on this subject, by Mr. Molyneux, that he thinks the petrifying power of the waters of the lake to be fabulous; and believes, that the petrified wood is found, only in the earth which surrounds, or which forms the bed of the lake, at the sides. He remarks, that none of the pieces he saw, were partly wood, and partly stone; nor did he ever see the bark petrified.

This wood is described, by Dr. Barton†, as existing in two different states. In the one kind, there is still an exact resemblance to wood, although it is now really stone. This is, generally, in small pieces, which are of a whitish colour, porous, and comparatively lighter than other stones; cleaving easily lengthways, grinding to a smooth surface, so as to be fit to whet knives; and have never yet been found with any wood contiguous to them. The other sort is found in much larger, harder, and more weighty pieces, which are black, both externally and internally. This sort is frequently found with much wood on the surface of the stones; and, most frequently, the internal parts of the stone are found to contain wood still existing in a soft state. Of this kind, two very large pieces are mentioned. The one was a stone, weighing 700 pounds, which was found two miles from Lough Neagh, on the side towards the river Camlin. This specimen appears to have been, externally, complete stone; but internally, evidently woody. The other specimen was as heavy as two men could lift, and the reverse of the former: the outer coat being of a woody nature, and the internal part entirely stone. The woody coat of this stone, when first found, was at least a foot thick, except at the ends. The stony parts of these masses are of a dark grey, approaching, in some parts, to a blue colour; but are generally stained yellow on the outside, from their laying in a bed of gravel.

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* Philos. Trans. No. 158, p. 554.

† Lectures in Natural Philosophy, &c. by Richard Barton, B. D. Dublin, 1751.

These stones are chiefly found at a point called Ahaness, in the county of Antrim; half a mile south of the mouth of the river Glenèvey. The bank at Ahaness is twelve feet high; between the bottom of which and the lowest water-mark in summer, there is a space of about ninety feet; which space, in winter, is sometimes covered with water. Upon digging a pit in this place, it appeared that the upper stratum is of red clay, four feet deep; the second stratum is of stiff blue clay, four feet deep; the third stratum is formed by a black wood, lying in flakes four feet deep; and under this is clay again. From the top of the stratum of wood to the surface, is a depth of seven feet; and before the water of the lake encroached so far on the land, it appears to have been nineteen feet.

In a paper of Mr. James Simons, contained in the Transactions of the Royal Society*, it is asserted, that the white wood-stones are generally found in the ground; at from about two to six miles distance from the lake, and sometimes very deep in the earth.

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* Vol. xliv. No. 481.

The black ones are always found in the water, or on the shores of the lough: sometimes in the mouths, or on the shores of rivulets, that empty themselves into it. Those which have wood continuous with them, have not yet been found above twenty yards distance from the waters of the lake; which is about the distance to which the waters reach in winter, and other times, when its waters are extraordinarily swelled. This gentleman observes, that the whetstones or hones, vulgarly so called, which are often sold for Lough Neagh stones, are not so; but are of a soft gritty kind, and are found near Drogheda.

There seems, however, little reason to believe, that the waters of Lough Neagh possess, at present, any petrifying power; since the supporters of this opinion, have not been able to adduce a single well supported fact, in proof of it.

Mr. Carew observes*, that "the Cornish tynners hold a strong imagination, that in the withdrawing of Noah's floud to the sea, the same took his course from east to west, violently breaking up, and forcibly carrying with it, the earth, trees, and rocks, which lay any thing loosely, neare the upper face of the ground. To confirme the likelihood of which supposed truth, they doe many times digge up whole and huge timber trees, which they conceive at that deluge to have been overturned and overwhelmed: but whether then, or sithence, probable it is, that some such cause produced this effect."

He also observes †, that "the ancient name of St. Michael's Mount, was *Cara Clowse in Cowse*, in English, the hoare rock in the wood: which now is, at every flood, encompassed by the sea, and yet at some low ebbes, roots of mighty trees, are discryed in the sands about it."

Camden not only notices these roots of mighty trees being seen in the sands; but remarks, that similar roots have been seen about

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* The Survey of Cornwall, written by Richard Carew, Esq. 1602, p. 7.

† Ibidem, p. 3.

Plymouth Haven, and other adjoining places. This learned antiquary has enumerated many parts of England, where subterranean trees have been discovered.

Childrey relates, that about two miles eastward from St. Michael's Mount, at low water, they cast aside the sand on the shore, and dig up turfs that are full of the roots of trees; and on some of these they have found nuts *. The tinners, he also says, do many times dig up whole and huge timber trees, which they think were overthrown, and have lain buried in the earth ever since the flood †.

Childrey also states, that in divers places, in the low grounds and champaign fields of the island of Anglesey, the inhabitants do every day find, and dig out of the earth the bodies of huge trees, with their roots; and fir trees of a wonderful bigness and length: which trees, in the opinion of Hugh Lloyd, were such as were cut down by the Romans in their time; because Tacitus saith, the Romans, when they had conquered this island, caused all their woods to be cut down, and utterly destroyed ‡. But from this opinion, as some are found with their roots on, Childrey, with propriety, dissents. He remarks, that there are also, on the shores of Cumberland, trees discovered by the winds at low water, which are else covered over with sand. And it is reported, he says, by the people dwelling thereabouts, that they dig up trees without boughs, out of the ground in the mossy places of this shire; and that, by the direction of the dew in summer; for they observe, that the dew never stands upon that ground under which they lie §.

This author, I believe, on the authority of Giraldus Cambrensis, states, that at the time when Henry II. made his abode in Ireland, were extraordinary violent and lasting storms of wind and weather; so that the sandy shore on the coast of this shire (Pembrokeshire)

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* Britannia Baconica, by J. Childrey, 1661, p. 10.

† Ibid. p. 6.

‡ Ibid. p. 15.

§ Ibid. p. 171.

was laid bare to the very hard ground, which had lain hid for many ages: and by further exposure, the people found great trunks of trees, which when they had digged up, they were, apparently, lopped, so that one might see the strokes of the axe upon them, as if they had been given but the day before. The earth looked very black, and the wood of these trunks was altogether like ebony. At the first discovery made by these storms, the trees (we speak of) lay so thick, that the whole shore seemed nothing but a lopped grove*.

At Charmouth, in Dorsetshire, is found a petrified wood, which agrees, in many of its appearances, with the larger masses of that of Lough Neagh; particularly in the dark bluish grey stone, with which it is sometimes invested, and in the softness which is sometimes discoverable in the wood thus inclosed.

Indeed there is hardly any part of Europe, in which subterranean wood is discovered more generally, than in England; there scarcely being a spot through the whole island, where, upon digging to any considerable depth, vegetable remains are not found. Thus we learn, from Dr. Plott, that at Wattington Park, in Oxfordshire, at the bottom of a pond, were found some tons of oak; and a pit being sunk 50 or 60 feet deep, many whole oaks were found, one of which was upright; one was also perpendicular, but inverted. All of them were dyed through, of a black hue, like ebony, but sound enough, and fit for many uses. Hazel nuts, and a large stag's head with the brow antlers, were also found here, the horn being as sound as the beam itself, and not at all dyed. In the same spot, two Roman urns were also found†.

Dr. Plot also describes a stone, found between Clifton and Nuneham Courtney, which, he says, represents a sound piece of ash: retaining the grain and colour so well and lively, that nobody, at sight, all likelihood the deluge laid along, and found growing on or near the places where we now find them; and if they grew near the places where they are found, as there are many signs they did, then there is no question but it was *terra firma* before that deluge *.

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* Britannia Baconica, p. 142.

† The Natural History of Oxfordshire, by Dr. Plott, p. 161.

In the fenny tract, called the Isle of Axholme, lying partly in Lincolnshire, and partly in Yorkshire, and extending a considerable way, are also found vast numbers of oak, fir, and other trees, lying somewhat above three feet in depth; and, near to them, their roots, which do still stand, as they grew, in firm earth below the moor †. Mr. Dugdale, in his book of Draining the Fens in England, concludes the cause thereof to have been "the muddiness of the constant tides, which flowing up Humber into Trent, left, in time, so much filth, as to obstruct the currents of Idle, Done, and other rivers, which thence flowed back, and overwhelmed that flat country."

Dr. Richardson, speaking of subterranean trees dug up at Youle, in Yorkshire, says—

"Some of these trees are so large, that they are used for timber in building houses, which is said to be more durable than oak itself. The country people hereabout call them fir-wood. The bate or texture of this wood is the same with fir, easily splitting: if burnt it sends out the same rosinous smell, and it affords the same coal. The branches do generally grow in circles, as the knots do yet testify: the knots do easily part from the rest of the wood, as is usual in fir-wood. The straightness and length of these trees, are also a presumption, that they must be such; if one consider, that some of these are nigh an hundred feet long; and at the bottom, not much above a foot in diameter. Their tops lay all one way, (viz.) with the current of the water. There are also oaks found there, though not in so great quantity. The vitriolic parts of the earth, in which they have lain, hath given them a black tincture quite through;

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* Mona Antiqua Restaurata, Henry Rowlands, sect. iii. p. 8.

† Philos. Transact. vol. viii. No. 69.

which they did most evidently belong, both by their situation, and the sameness of the wood) with their tops commonly north-east; though indeed the smaller trees lie almost every way across those; some above, some under; a third part of all which are pitch trees, commonly called firs, some of which have been found of thirty yards length and above, and have been sold to make masts and keels of ships of. Oaks have been found of twenty, thirty, and thirty-five yards long, yet wanting many yards at the small end. Some of which have been sold for four, eight, ten, and fifteen pounds apiece; which are as black as ebony, and very lasting and durable in any service that they are put unto. As for ashes, it is commonly observed of them, that their constituent parts are so dissolved, that they become as soft as earth, and are commonly cut in pieces by the workmen's spades; and, as soon as flung up into the open air, fall away into dust; but all the rest, even the willows themselves, which are softer than ashes, preserve their substance and texture, he says, to this day. He adds, I have seen some pitch or fir trees, that, as they have laid all along, after that they were fallen, have struck up great branches from their sides, which have grown unto the thickness and height of considerable trees.

Many of those trees, he observes, of all sorts, have been burnt; but especially the pitch or fir-trees; some quite through, and some all on a side; some have been found chopped and squared, some bored through, other some half riven, with great wooden wedges and stones in them, and broken axe heads, somewhat like sacrificing axes in shape: and all this in such places, and at such depths, as could never be opened from the destruction of this forest, until the time of the drainage. Near a great rock, in the parish of Hatfield, were found eight or nine coins, of some of the Roman emperors, but exceedingly consumed and defaced with time. It is very observable, he adds, that upon the confines of this low country, between Birmingham and Brumley, in Lincolnshire, are several great hills of

The Rev. W. Borlase relates, that great numbers of subterranean trees were found on the shore at Mount's Bay, Cornwall. These trees were very large, and appeared to be oaks, hazel, and willow trees: they were found three hundred yards below full sea mark; and when the tide is in, have at least twelve feet of water above them. This, he thinks, confirms the tradition, already noticed, that St. Michael's Mount, now half a mile inclosed with the sea, when the tide is in, stood formerly in a wood *.

Sir John Hill states, that he often met with pieces of wood, very little altered from their original state, in strata of loam among gravel; and even in solid beds of stone, particularly at the great quarry, at Mr. Allen's, near Bath, in which he saw part of an elm, of more than four feet in length, which was still soft enough to be easily pierced with a knife †.

When the mind is engaged in the consideration of a subject, so interesting as that to which I am endeavouring to attract your attention; it is highly gratifying to find, that necessary investigations have been made by men, whose learning and abilities have engaged our respect. The following observations, independent of the importance they derive from their authors, are in themselves so highly interesting, that no apology can be necessary for laying them before you, almost unaltered in their form.

In September, 1796, the Right Honourable the President of the Royal Society, accompanied by Dr. Joseph Correa de Serra, went to Sutton, in Lincolnshire, to examine the nature and extent of certain islets of moor, chiefly composed of decayed trees, situated along that coast, and visible only in the lowest ebbs of the year.

These islets, according to the most accurate information, extend at least twelve miles in length, and about a mile in breadth, opposite to Sutton Shore; and consist almost entirely of roots, trunks, branches, and leaves of trees and shrubs, intermixed with some

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* Philos. Transact. vol. i. part 1. † Natural History of Fossils. p. 638.

leaves of aquatic plants. The remains of some of these trees were still standing on their roots, while the trunks of the great part lay scattered on the ground, in every possible direction. The barks of trees and roots appeared, generally, as fresh as when they were growing; in that of the branches particularly, of which a great quantity was found, even the thin silver membranes of the outer skin were discernible. The timber of all kinds, on the contrary, was decomposed, and soft in the greatest part of the trees: in some, however, it was firm, especially in the roots. The people of the country have often found among them very sound pieces of timber, fit to be employed for several oeconomical purposes.

The sorts of wood, which are still distinguishable, are birch, fir, and oak. Other woods evidently exist in these islets, of some of which the leaves were found in the soil. In general, the trunks, branches, and roots of the decayed trees were considerably flattened; similar to the *surturbrand* or fossil wood of Iceland, as well as to that found in the lake of Thun, in Switzerland.

The soil to which the trees are affixed, and in which they grew, is a soft greasy clay; but for many inches above its surface, the soil is entirely composed of rotten leaves, scarcely distinguishable to the eye; many of which may be separated by putting the soil in water, and dexterously and patiently using a blunt spatula or knife. By this method the Doctor, from whose account this extract is made, obtained some perfect leaves of *ilex aquafolium*, which are now in the herbarium of the Right Honourable Sir Joseph Banks; and some other leaves, which, though less perfect, seem to belong to some species of willow. In this stratum of rotten leaves, could also be distinguished some roots of *arundo phragmites*.

By examining a well, dug at Sutton, by Joshua Searby, these gentlemen discovered, that a moor of the same nature is found under ground in that part of the country, at the depth of sixteen feet; consequently very nearly on the same level with that which constitutes the islets. The disposition of the strata, was found to be nearly as follows:

Clay	16 feet
Moor, similar to that of the islets	3 to 4 feet
Soft moor, like the scouringof a ditch bottom, mixed with shells and silt	20 feet
Marly clay	1 foot
Chalky rock	from 1 to 2 feet
Clay	31 yards
Gravel and Water; the water having a chalybeate taste.	

In order to ascertain the course of this subterraneous stratum of decayed vegetables, Sir Joseph Banks directed a boring to be made, in the fields belonging to the Royal Society, in the parish of Mablethorpe. Moor, of a similar nature to that of Searby's well, and the islets, was found, very nearly on the same level, about four feet thick, and under a soft clay.

The whole appearance of the rotten vegetables which were found, perfectly resemble, according to the remark of Sir Joseph Banks, the moor which, in Blankeney Fen, and in other parts of the East Fen, in Lincolnshire, is thrown up in the making of banks; barks, like those of the birch tree, being there also abundantly found. The moor extends over all the Lincolnshire fens, and has been traced as far as Peterborough, more than sixty miles to the south of Sutton. On the south side, the moory islets, according to the fishermen, extend as far as Grimsby, situated on the south side of the Humber; and it is a remarkable circumstance, that in the large tracts of low land, which lie on the south banks of that river, a little above its mouth, there is a subterraneous stratum of decayed trees and shrubs, exactly like those observed at Sutton; particularly that of Axholme Isle, and that of Hatfield Chace, which have been already described.

Little doubt can be entertained, of the moory islets of Sutton being a part of this extensive and subterraneous stratum, which, by some inroad of the sea, has, in that part, been stripped of its covering of soil. Sufficient reasons for this opinion, the Doctor thinks, are yielded by the identity of the levels, as well as that of the species of trees; the roots of these being affixed, in both, as to the soil where they grew; and, above all, the flattened shape of the trunks, branches, and roots, found in the islets, which can only be accounted for by the heavy pressure of a superinduced stratum. Such a wide spread assemblage of vegetable ruins, lying almost in the same level; and that level generally under the common mark of low-water, must naturally strike the observer, and give birth to the following questions:—1. What is the epoch of this destruction? 2. By what agency was it affected?

Whilst endeavouring to answer these questions, the learned writer supposes, the fossil remains of vegetables, hitherto dug up in so many parts of the globe, to belong to two different states of our planet. The parts of vegetation, and their impressions, found in mountains of cotaceous, schistous, or even sometimes of a calcareous nature, are chiefly of plants now existing between the tropics; which could neither have grown in the latitudes, in which they are dug up; nor have been carried and deposited there by any of the acting forces, under the present constitution of nature. The formation, indeed, he justly remarks, of the very mountains in which they are buried; and the nature and disposition of the materials which compose them, are such as we cannot account for, by any actions, and reactions, which, in the actual state of things, take place on the surface of the earth.

The consideration of this order of fossil vegetables obliges us, in the opinion of Doctor de Serra, to recur to that period in the history of our planet, when the surface of the ocean was at least so much above its present level, as to cover even the summits of those secondary mountains which contain the remains of tropical plants. But whether we suppose these plants to have grown near the spot where they are found, or to have been carried thither, from different parts, by the force of an impelling flood, it is equally difficult, he remarks, to conceive, how organized beings, which, in order to live, require such a vast difference in temperature and in seasons, could live on the same spot: or, how their remains could (from climates so widely distant) be brought together in the same place, by one common dislocating cause. To this ancient order of fossil vegetables belong whatever retains a vegetable shape, found in or near coal mines, and (to judge from the places where they have been found) the greater part of the agatized woods.

The second order of fossil vegetables, comprehends those which are found in the strata of clay and sand; materials which are the result of slow depositions of the sea, and of rivers; agents still at work, under the present constitution of our planet. These vegetable remains are found, in such flat countries as may be considered to be of a new formation. The vegetable organization still subsists, at least, in part; and this vegetable substance has suffered a change only in colour, smell, or consistence; alterations which are produced by the developement of their oily and bituminous parts, or by their natural progress towards rottenness. To this description of fossil vegetables, the decayed trees, and other vegetable remains, belong, which constitute the greater part of the mass of which this moor is formed. Although these trees are standing in their native soil, Dr. de Serra reminds us, that the level in which they are found, cannot be the same as that in which they grew; and we should, therefore, conclude, that the forest here described, grew in a level high enough to permit its vegetation, which could not have been the case, if it had been so near the sea, or below the common level of must again repair with you to distant parts, to shew you, that where-ever attentive observations have been made, proofs of this fact have been found.

Thus Mons. de la Hire gives a particular description of part of the petrified trunk of a palm tree, which he had obtained from some part of Africa.

The petrified trunk of a palm tree was also found in the desert near the isthmus of Suez, and transmitted to the class of natural history by General Regnier, member of the institute of Egypt.

In the account of Mr. Horneman's travels, in the years 1797 and 1798, undertaken for the purpose of exploring the interior parts of Africa, we learn, that in that vast desert which forms the natural boundary of Egypt, petrified wood is found, of various forms and size. Sometimes are seen whole trunks of trees, of twelve feet circumference, or more; sometimes only branches of twigs, scarcely of a quarter of an inch diameter; and sometimes merely pieces of bark, of various kinds, and, in particular, of the oak, are to be found. Many of the great stems yet retain their side branches, and in many the natural timber has undergone so little change, that the circular ranges of the wood are discernible, and especially in those trunks which were, apparently of oak. The interior of other bodies of timber was become a petrifaction, shewing no distinctions of grain or fibre, but bearing the appearance of mere stone; though the outward coat and form of the substance clearly denoted the tree.

Mr. Horneman was informed by several Arabs, that in travelling over this desert, petrified trees were often found upright, and as if growing in the soil; but he presumed, respecting those he did not see, from those he did actually inspect, that they were trunks raised by hand, round the base of which the sand had quickly gathered before the winds, and formed a mound, as if heaved up by a root. The colour of the petrified wood is in general black, or nearly so;

adopted, as appears to be best calculated to place the opinions I offer in the fairest point of view. I shall, therefore, in the first place, bring together those descriptions of these substances, and of the circumstances attendant on their discovery, as appear to be the most valuable and interesting; and then shall endeavour to point out the nature of these various modifications of vegetable matter, and the different processes on which they depend.

But, previously to entering into a particular examination of the changes which take place in vegetables, in the several processes to which they are subjected, whilst passing into a state of mineralization; it is necessary to give some slight account of the substances of which they are composed, during their vegetable state; and of such chemical changes as appear to be subservient to the offices of vegetation.

Vegetables, besides containing oils, acids, alkalies, earths, and metals, in common with substances of the animal and mineral kingdoms, do also contain the following substances, which are peculiar to the subjects of the vegetable kingdom:—Albumen, gluten, jelly, starch, gum, sugar, extract, tannin, wax, resins, camphor, caoutchouc, wood, cork. The analysis of these substances manifest, that oxygen, carbon, and hydrogen, entering into a triple combination, constitute, with some of the earths, the greatest part of their mass. In several of these substances, nitrogen is also found to exist; and in some, sulphur has been found. Phosphates of lime, &c. have likewise been found in the analysis of some vegetables; the phosphoric acid having been, doubtlessly, derived from the phosphorus yielded by the decomposition of animal matters, in the soil in which these vegetables grew.

It is now well known, that all vegetables derive their origin from seeds, which consist of *cotyledons* or lobes, inclosing a *radicle*, and a *plume*. When any seed is placed under circumstances favourable to vegetation, the radicle, which is a small round white body, is genious experiments of Hassenfratz have furnished us with additional means of solving this interesting question. Having previously ascertained, by analysis, the quantity of carbon contained in a given weight of certain bulbs, he caused several of these bulbs, previously weighed, and the quantity of carbon they contained thereby previously known, to vegetate in pure water, until they had flowered; and had appeared to have acquired the *acmé* of their growth. He then subjected them, with every part which had fallen off during their vegetation, to a strict analysis, and found that the quantity of carbon, which the whole of the plant, thus collected, contained, was rather less than that which had existed originally in the bulb itself, from which the plant had proceeded. Plants made to vegetate under these circumstances, are, however, far from being in a state of perfection. They never produce any seed; their power of vegetation becomes diminished; and if not allowed to derive other nutriment from the earth itself, they at last cease to vegetate at all. Hence it appears, that the water did not add to the stock of carbon, so necessary to the growth of the plants, but only served for the diffusion of that which the bulb originally contained: water, therefore, cannot be considered as the sole food of plants.

If water does not constitute, alone, the food of plants, it is, however, absolutely necessary to their existence; serving as the vehicle, by which those substances, from which they derive a larger portion of nutriment, are conveyed through their system of vessels. Water is also, most probably, so acted on in the vegetable system, that it is resolved into its two simple principles, hydrogen and oxygen: both of which are well known to exist, in almost every vegetable substance; and are presumed to be absolutely necessary to the performance of various important functions, in the vegetable œconomy.

In all vegetables is discovered, by analysis, a considerable por-

Analysis of the Granitic Soil.

73,25	Silica,
13,25	Alumine,
1,74	Lime,
9,00	Iron and manganese.
97,24	

Analysis of the Calcareous Soil.

98,000	Carbonate of lime,
0,625	Alumine,
0,625	Oxide of iron,
0,025	Petroleum.
99,275	

Analysis of the Fixed Substances contained in the Pinus Abies, growing in the Granitic Soil.

13,49	Silica,
14,86	Alumine,
46,34	Carbonate of lime,
10,52	Metallic oxides,
3,60	Pot-ash,
4,24	Alkaline sulphates and muriates,
0,77	Carbonate of magnesia.
99,82	

Of the Fixed Substances, contained in the Pinus Abies growing in the Calcareous Soil.

63	Carbonate of lime,
16	Alumine,
15	Alkalies and alkaline sulphates and muriates.
94	

The absorption of earths, metallic oxides, and various saline substances, for the accomplishment of important purposes in the vegetable oeconomy, cannot, therefore, be in the least doubted. Nor can there exist the least impropriety, in considering these substances, as well as phosphorus and sulphur, when thus imbibed, as having constituted a part of the actual food of plants.

When the fineness of the fibrillæ are considered, in which the roots terminate; and which may be supposed to contain the orifices of that class of absorbents: and when the minuteness of the pores which are found on those parts of the plant which are above ground are also considered, there seems to be great reason to suppose, that all those substances, which are imbibed as food, first pass into a state of aqueous or gaseous solution.

A circumstance which takes place during the germination of seeds may be considered as proving that this is the case. A farinaceous matter, it has been already observed, constitutes the substance which forms the cotyledons of the seed, and is destined

LETTER IX.

RESOLUTION OF VEGETABLES INTO THEIR FIRST PRINCIPLES.... FIRST STEP IN THE MINERALIZATION OF VEGETABLES....VEGETABLE MOULD....IGNIS FATUUS.

In tracing the transition of vegetable matter, into a mineral state, it is proper to commence our remarks by an examination of the changes which plants undergo, immediately on the extinction of vegetable life.

When from accident, or in consequence of the attainment of the full period of maturity, a tree or a forest falls, a resolution of composition necessarily succeeds: the constituent parts separate, and the elementary, or simple principles, disengaged from those connexions into which they had been forced by the energies of vegetable life, now enter into new combinations, resulting, almost, from chemical attractions merely.

The epidermis, as well as the parenchyma of the leaves, and the other succulent parts, soon become resolved into a soft mass, which yields an unpleasant odour, and which acquires much of its moisture from the extravasation of the sap and other vegetable juices. The mass derives, perhaps, also an increase of its fluidity, from the hydrogen and oxygen, which had been employed in the formation of various parts of the vegetable, being now let loose, and entering into a new combination, by which water is formed. Another portion of the hydrogen becomes also volatilized, and uniting with a portion of carbon, forms carburetted hydrogen gas, and other inflammable gases, somewhat similar in their composition. In the decomposition of those plants, into the composition of which nitrogen enters, this principle enters directly into union with the hydrogen, at the moment of their except to notice two curious and interesting phenomena, which it sometimes offers to our observation.

The first of the phenomena, here meant, is that which is termed the *Ignis fatuus*, or Will of the Wisp. This is well known to be a lambent flame, appearing at night, over marshy lands; and which, by its flitting motion, and by the sudden disappearance, and as sudden renewal of its flame, serves frequently to mislead the wandering, and even cautious traveller.

Dr. Shaw has furnished us with the following curious account of the phenomena yielded by this extraordinary meteor, of which he was enabled to obtain the closest inspection: He says, that in travelling by night, in the beginning of April, through the vallies of Mount Ephraim, we were attended, for the space of an hour, with an *Ignis fatuus*, that displayed itself in a variety of extraordinary appearances. For it was sometimes globular, or else pointed like the flame of a candle; afterwards it would spread itself, and involve our whole company in its pale and inoffensive light; then at once contract, and suddenly disappear. But in less than a minute, it would begin again to exert itself, as at other times; running along from one place to another, with great swiftness, like a train of gunpowder, set on fire; or else it would spread and expand itself over more than two or three acres of the adjacent mountains; discovering every shrub and tree that grew upon them. The atmosphere from the beginning of the evening, had been remarkably thick and hazy; and the dew, as we felt it upon our bridles, was unusually clammy and unctuous *.

The late discoveries in chemistry, give us reason to hope, that an explication of this extraordinary appearance may, before long, be obtained. It is generally attributed to some inexplicable agency of the electric fluid on the inflammable air of marshes; but it seems rather to depend on some hitherto unknown combination of phosphorus, with a solution of carbon or sulphur, in hydrogen gas, separated from the wetted vegetable mould.

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* Travels, or Observations relating to several Parts of Barbary, and the Levant, by Thomas Shaw, D.D. F.R.S. 2d edition, 1756, p. 334.

Gengembre has discovered, that by mixing pure fixed alkali or lime, with a small quantity of water containing phosphorus, the hydrogen of the water is liberated, and immediately enters into combination with a portion of the phosphorus; forming what he terms phosphorised hydrogen gas, but which is more properly distinguished by the term phosphuretted hydrogen gas. This gas exhibits phenomena, which certainly approximate more nearly to those of the *Ignis fatuus* than any substance, whose properties have been hitherto noticed. Immediately on its coming in contact with the air of the atmosphere, on its passage through the water, it inflames with a beautiful phosphoric light, but soon disappears, leaving behind it, if the air is still and serene, a ring of thin smoke, which beautifully undulates, and extends its circle as it rises. It is true, that in this case actual inflammation takes place; whereas in *ignes fatui*, the illumination appears to be that of phosphorescence light only; but that the subsequent industry of chemists will enable them to imitate this phenomenon still more closely, seems very probable. Indeed, there seems to be reason for expectation, that such a result may be the reward of a careful series of experiments, in which the phosphorus is combined, in different doses, with other gases, containing various proportions of the several simple combustible bodies—perhaps the gaseous oxide of carbon might be found well calculated to repress the combustion, whilst it permitted the emission of the phosphoric light. The volatile alkali, also, in such experiments, might become an useful agent; since, in the distillation of the salt, formed by the union of this alkali with phosphoric acid, a gas comes over, which does not instantaneously inflame, but displays a phosphoric light, when it comes in contact with oxygen gas.

The other phenomenon, which is yielded by the mould formed of the mineralized remains of vegetables, is a corruscating light, produced by its percussion under certain circumstances. This phenomenon has been seen by Dr. Plot and others. Dr. Plot's account of it is as follows:—

"Under the uppermost turf, in their moorish boggy grounds, they also dig peats, which, because they order much after the same manner, as has already been described in Oxfordshire, I pass them over, and proceed to another black, moist, and rotten sort of earth, that lies just under the turf in heathy soils, such as Archer Moor, near Berresford, and upon a hill called the Gun, above Rudyerd Hall, where, as I was seriously told by the worshipful and most ingenious Charles Cotton, Esq. Thomas Rudyerd, of Rudyerd, Esq. and Mr. Gent, of Asbourn, if one ride in a dark night in so wet a season, that a horse breaks through the turf, and throws up this black, moist, spongy sort of earth, he seems to fling up so much fire, which lies shining upon the ground like so many embers; by the light whereof, one horse may trace another, though at some distance, and it be never so dark; it continuing light upon the ground, and being gradually dying away, for near a quarter of an hour. To which let me add another agreeable relation, whereof I was informed by that worthy loyal gentleman Capt. Thomas Lane, of Bentley, Esq. who, endeavouring to help a friend and kinsman (one Mr. Jones), who casually fell in a ditch, in Bescott Grounds, in the night time, and having stirred the mud and dirt pretty much in performing that good office; they presently found their gloves, bridles, and horses, as far as the water or dirt had touched them, all in a kind of faint flame, much like that, as he described it, of burnt brandy, which continued upon them for a mile's riding *."

The foregoing account, exactly agrees with a curious history of the same phenomenon, contained in the collection of manuscript

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* The Natural History of Staffordshire, by Dr. Plot, p. 115.

communications, to the Royal Society, in the library of the British Museum. It is entitled, "A Relation of a firey Appearance in the Impress of Mens and Horses Feet," and was given in these words, by Dr. Croon, about the year 1665:

"Being Monday, on my return with Sir John Courton, bart. and his clerk, Wm. Stephens, from the Lord Bishop's visitation at Launceston, about an hour, in a misty dewy night, on Hinxon, about a mile beyond Kellington, in Devonshire, in Launceston road, in a moorish place of some forty feet in length, the impress of our horses and our own feet upon the ground, appeared fiery, much more shining than glow-worms; the grass we gathered in those places where we or our horses trod, reserved the lustre in our hands when we came to the waters within a quarter of a mile from Kellington; where, watering our horses, we observed it, but almost extinguished, only a spark here and there. At Newton, two miles thence, we viewed it by candle-light that night, as also the next day, and found it coarse spiry grass, of an inch, or little more, in length, such as ordinarily grows on downs *."

That this phenomenon, as well as that of the *Ignis fatuus*, depends on some peculiar modification of phosphorus, there seems to be no difficulty of admitting. Nor can there exist any doubt, as to the source whence volatile alkali, and even the phosphorus itself, is derived, when it is recollected, that, with this crust of mould, a considerable quantity of animal matter must be blended, proceeding from the myriads of insects which had fed on the vegetables, the remains of which it is composed. From the resolution of animal matter in subterranean situations, must also proceed the various metallic and other phosphates, so eminent in their brilliance and colours.

Yours, &c.

* Mr. Ayscough's Catalogue, 698, p. 47.

LETTER X.

PEAT OR TURF....DESCRIPTION OF....VARIOUS KINDS....LENGTH OF TIME KNOWN....FOUND IN VARIOUS PARTS OF THE WORLD.

THE substance, to which I next wish particularly to attract your attention, is one which has been seldom, or hardly ever, considered in relation to the bodies termed petrifactions; but which, I suspect, is very nearly connected with those which derive their origin from the vegetable kingdom. Indeed, I shall endeavour to prove to you, that most of these bodies which have obtained so considerable an alienation from their original nature, have first passed through an intermediate state; resembling that, in which the substance which is the subject of our immediate inquiry, is always found to exist.

The substance here alluded to, is peat or turf; well known to the inhabitants of most lowland countries, for the advantages it affords them by its combustible quality. It is found in various parts of the world, forming immense tracts, at various depths. It is a soft but compact substance; its colour being of a bright reddish brown. As it dries, upon exposure to the air, it becomes soon darker; the darkness increasing, in the best peat, until it acquires almost the blackness of coal: at the same time it becomes a hard, tough, weighty, mass, very difficult to be cut or even broken; and which, in general, contains many remains of vegetable matter. It absorbs water, and retains it so strongly, as to be found almost always in a wet state, in its natural situation; hence, when near the surface, it forms bogs, which are exceedingly dangerous for such animals as attempt to pass over them. The best peat is smooth, and cuts clean with the peat-spade, being almost of the consistence of soap.

Like clay that has been burned, peat, on being dried, loses the property of forming a tenacious mass, by the addition of water. When properly dried, which is accomplished, by cutting it into square pieces of the size of a brick, exposed to the conjoint action of the sun and air, the peat becomes a very combustible substance; burning, when pure, with a clear bright flame, and yielding a hard firm charcoal, which burns with a vivid glow, until reduced to a very small portion of very light and white ash. Sometimes it contains small branches and twigs, in which the woody fibres still possess so much of their original state, as to give considerable resistance to the peat-spade. Oftentimes it appears to be a composition of the roots, branches, twigs, leaves of trees, various parts of plants, grass, straw, &c. but little altered in their form, although in their nature, they are now rendered intirely different.

The varieties here enumerated, appear to be the consequences of different degrees of perfection, to which the natural process, to which these substances have been exposed, has proceeded. But it is not the smaller and the less hard parts of vegetables only, which are thus found imbedded; since, frequently, large trees are found in different parts of the peat, increasing the expence and adding to the trouble of the peat-digger, by the obstacles they yield to his operations.

Other varieties, in its appearance, are frequently observable; depending on the quantity of the extraneous matters, with which it has become blended. When its purity is much impaired, it is found to burn with considerable less freedom; and a close inspection will shew, by its being not smooth in its cut, but gritty in its substance, that its impurity proceeds from an intermixture of earth. If the peat be good, and contain but few impurities, it burns with a clear bright flame, leaving ashes of a light colour; but if much earth is blended with it, the ashes are more plentiful: and, from the ignition having been thereby impeded, are of a darker colour. If, as is frequently the case, it contains much pyrites, or ferruginous earth, then a heavy reddish ash is left.

Adrianus Junius observes, that there are several kinds of these turf-like substances. The first kind, which he describes, is of a reddish colour, poor, and spongy; very light, and of but little value; being only used to heat brewers' coppers. Whilst burning, it gives to the countenance a livid, cadaverous hue; making men appear like ghosts: it, at the same time, produces a noxious vapour, which occasions fainting; to prevent which it is sprinkled with salt. The second kind is more dense, of a blackish brown colour, and is intersected by twigs and rushes, in various directions. It is heavier than the former kind, and more generally useful. The third kind is heavy, and sinks in water, which the former kinds do not. It is of an ash colour, and is dug in a sandy soil: it takes fire slowly, but continues to burn a long time. He observes, that there is another kind, formed of the salt earth in Zealand; and besides these, he remarks, there is another kind, which is obtained from the fatty mud, which is dragged from the bottom of ponds, and is afterwards drained, and so dried by exposure to the air, as to render it useful*.

Schoock remarks, that the peat, which is dug from the deeper parts of the earth, is more firm, and is of much higher estimation, than that which is found nearer the surface.

The peat is, sometimes, found even near the surface, excepting a a slight covering of mould, formed by the more recent decomposition of vegetable matter. Sometimes this surface is tolerably well stocked with heath and other vegetables; but more frequently it presents to the eye an extensive barren flat moor, which, except in the dryest seasons, is so wet and spongy, as to be intirely impassable.

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* Historia Bataviæ, cap. v.

According to Dr. Anderson, well known for his vigilant attention to those circumstances, on which the comforts of humble life depend, it is found at various depths, under strata differing very considerably in their composition, thickness, and number.

Peat, as Mr. Jameson observes, is most commonly to be found in vallies and plains, where it forms very extensive beds; varying in their depth, from one foot to full forty feet. Sometimes it is discovered at the sides of mountains; but even there its beds preserve an horizontal situation. Mountains, upwards of two thousand feet high, in the Highlands of Scotland, have their tops covered with peat of an excellent kind. In Germany,.it is also found at very great heights; thus the Blogsberg, a high mountain in Lower Saxony, and the Brohen, the highest mountain of the Hartz, are covered to their summit with peat. It is also found at the bottom of ponds and canals; and is sometimes brought up on the coast of Holland, by the flukes of anchors; and also cast on shore in stormy weather, which has induced some to imagine it to be of marine origin. In the harbour of Oban, in Argyleshire, one part of the bottom appears to be formed of quick moss, which affords no sure anchorage. The depth of the sea is there about twenty fathoms.

In Galloway is the great moss of Cree, lying near to the sea, a little higher than flood-mark at spring tides. Near Dumfries is Locker Moss, only a few feet above high water mark: it is about ten miles in length. In the island of Lewis, one of the Hebrides, there is an extensive peat moss, thirty miles long, having its surface but little elevated above that of the sea*.

Peat appears to have been long in use, as fuel, in different parts of Germany. Thus Æneas Sylvius Piccolominæus, in 1458, in his History of the Military Transactions of Frederic III. having occasion to speak of some part of Friesland, rendered worthy of notice by some interesting military event, describes it as "a smooth and

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* Anderson on Peat-Moss.

and marshy plain; abounding in grass, but without wood. The inhabitants supporting their fires by a bituminous turf, mixed with the dried dung of oxen."

Ludovicus Guicciardinus, who wrote very early on the geography and natural history of Holland, remarks, that the combustible turf, called by the names of *torff* or *turf*, which abounds in Holland, is of so much consequence as to have had the strongest claim to his attention.

Cuthbert Tonstall, Bishop of Durham, in the reign of Henry VIII. notices the very general use of turf, as fuel, in Zealand; the heavy inconveniences arising from the smoke of which, he complains of to Erasmus in a very energetic lamentation. If, says he, you remain at home in the city, the smoke of the turf (for, says he, they burn this in the place of wood) fills your nostrils from the surrounding neighbourhood. These, when dug from moist and salt places, however much they may have been dried in the sun, yield a smoke, whilst they burn, which penetrates into your very breast, and attacks, at once, your nostrils, head, and chest.

Turf, it is probable, might be found in most parts of the world: the lowlands of almost every country of Europe possess it, and it particularly abounds in many parts of Holland and of Germany, in Brabant, Transilvania, Groningen, Zealand, Friesland, England, Scotland, and Ireland, and indeed in all the northern parts of Europe: being, in several places, the only fuel which the inhabitants can obtain*.

Cæsalpinus observes, that in Œland, a peninsula in the Netherlands, a black mud is obtained from the marshes, which, being made into clods, and dried, is used for the purpose of making up fires, being rendered a species of coals †.

Jonas Arngrim, who wrote in 1592, says, that the peat which is dug for fuel in Iceland, is of two kinds; the one, which is found growing immediately under the surface of the earth, he observes, is light and spongy; whilst the other, which is much deeper in the ground, and is dug up from the pits, is more heavy and dense*.

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* Erasmi Epistolæ. lib. iii. † Andr. Cæsalpin. lib. ii. cap. 53.

Quado† says, that in West Friesland the earth is fatty and bituminous; and that, being dried in the wind, it serves for fuel instead of wood; but is very different from the coal of Namur, Liege, Hanault, &c.

Libavius‡ says, the inhabitants of the lower parts of Germany employ for fuel that which they term *darry* and *dorfen*, which is, he says, a mass of roots, blended with a bituminous earth.

Schoockius, who wrote expressly on peat in 1658§, and does not admit its vegetable origin, thinks that Libavius should rather have said, that the bitumen in certain peats is so coloured and diversified as to resemble dried roots.

Darria, *derrie*, or *darinck*, derived from the Danish word *darren*, signifying to burn, he says, is a substance which, even at that time, was dug in Zealand, and chiefly in Wallachia, for fuel. He describes it as a bituminous matter, thrown on shore by the sea, and which has been afterwards covered by the earth. At one time it was dug, with so much eagerness, for the salt, which, by certain processes, it was made to yield, that a strong law was passed, to prevent the farther digging for this substance, lest the shore should be so weakened, that it would not be able to resist against the violence of the waves. In the year 1515, however, Charles V. harassed by the petitions of the poor, who had no other means of obtaining fuel, was again obliged to permit it to be dug.

Mr. Tooke informs us, that in Siberia, there are great plenty of morasses, and of various magnitudes. Thus the northern verge of Siberia, towards the shores of the Frozen Ocean, for several hundred versts in width, is one prodigious watery morass, grown over with moss, and entirely destitute of wood, and which, in summer, is only thawed to the depth of about a span*. In the interior of the empire we meet with smaller; and many of the forests have a swampy bottom. He describes them as—1st, simply low watery land;—2d, swamps, which yield turf formed out of the moss, and even at times produce a little hay;—3d, bottomless morasses, which appear to be lakes grown over: they frequently will bear neither man nor beast;—4th, moss-morasses, the deep and useless moss of which will permit neither grass nor a shrub to grow, or at most, only a few wretched low sticks of fir, &c. which presently wither and die. They are absolutely unprofitable; or at least they are held to be so †.

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* Brevis Commentarius de Islandia, Hoolum. 1592. † Lib. iv. cap. 37.

‡ Lib. iv. de Origine Rerum.

§ Martini Schoockii, Tractatus de Turfiis seu Cespitibus bituminosis. Groningæ, 1658.

Dr. Woodward observes, that marsh or turf earth, containing in it nuts, twigs of trees, shrubs, grass, sedge, &c. is found in various parts of England. He particularises several places, where it is found to abound very much. He obtained it from Hampstead Heath, and from Godalming, in Surrey. At Wilmestow, near Knutsford, in Cheshire, it lay uppermost in the moss, and next the surface; and seemed to be made up only of the shivers, or husks, and other parts of *juli* of hazel, alder, poplar, &c. There is also great quantities of this kind of turf in the northern parts of Yorkshire, and in the bishoprick of Durham. About a mile from Langrow, in Cumberland, is a stratum of bituminous earth, three feet thick, which contains parts of the trunks of trees, leaves, sprays of shrubs, and other vegetable substances, in such quantity that the far greater part of the stratum seemed to be formed by them. It also abounds near Outhorn in Yorkshire, at Kendall in Westmoreland, in Windsor Forest, in the Isle of Wight, and various other places. In that which was dug up in the Isle of Wight, besides the twigs and leaves the kernel having entirely perished. In the mass were also contained the trunks of several trees, of which, he thinks, the trunks of the yew trees, some of which were about fourteen or sixteen inches in diameter, were the least decayed. The willow trees, which were two feet and upwards in diameter, retained a whitish colour like touchwood, and were even softer than the adjoining earth or moor-log. The moor-log appeared at about three and a half or four feet under the marsh ground, and differed in thickness, in different parts. Up the Thames, at Deptford, it was six feet in thickness. In Woolwich Reach, where Captain Bronsden had then been repairing his wharfs, over against the ballast wharf, it was between seven or eight feet thick. In Plumsted Levels, just against Barking Creek, its thickness was full nine feet; its thickness, as well as its breadth, gradually increasing down the river, on both sides. None of it, he says, was to be seen where the course of the river cuts into the high-land, as at Woolwich, Erith, and Purfleet. Beneath the moor-log was a stratum of blue clay, and under this gravel and sand. Stags' horns were likewise found in different places, a little above the vein of moor-log.

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* Pallas's Travels, vol. iii. p. 23.

† View of the Russian Empire, &c. by William Tooke, F.R.S. London, 1800, p. 77.

The description of the peat at Newbury, in Berkshire, will serve to give a tolerably correct idea of the appearances it generally presents in this country; and will also shew that it does not seem to differ, in any thing material, from that, which we have seen, exists in the other parts of the world*.

The peat found in the middle of a valley, across which the town of Newbury lies, north and south. The river Kennet runs along the middle of this valley, which is about a mile broad, and the peat is found on each side of it, extending in all, for about a quarter of a mile, to about half a mile in breadth; and in length, along the valley, about nine miles westward, and about seven miles eastward;

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* Philos. Trans. vol. L. part i. p. 109.

A great many horns, heads, and bones of several kinds of deer, the horns of the antelope, the heads and tusks of boars, the heads of beavers, &c. are also found in it: and I have been told, says the learned gentleman who transmitted the account to the Royal Society, that some human bones have been found, but I never saw any of these myself, though I have of all the others.

Mr. Aikin, whose Journal of his Tour through North Wales is replete with most interesting and useful remarks, speaking of the vallies among the mountains of Llangynnog, Cader-Ferwyn, and Sylattyn, in North Wales*, says, the soil is peat, a yard or more in depth, lying upon a thin stratum of rounded pebbles, chiefly quartz, with some schistus: the bottom of the bogs is a grey clay, formed, probably from the decomposition of the rock. Near Aberdovey, in Merionethshire, he observed a considerable peat-moss, extending along the shore to Tomyn, reaching into the sea to an unknown extent, from which the inhabitants dig their fuel.

Whole bodies of trees, according to the relation of Dr. Gerard Boate, are frequently found, in Ireland, by the turf diggers, very deep in the ground. And it is worthy of observation, he says, that trees and trunks of trees are, in this manner, found, not only in the wet bogs, but even in the heathy ones, or red bogs; as in that by the Shannon side, in which bog the turf diggers do many times find whole fir trees, deep in the ground: whether it be that those trees being fallen, are by degrees sunk deeper and deeper, or that the earth in length of time be grown over them†.

Not only the presence of fossil trees in beds of turf, but also the existence of this substance at a prodigious height, is related, by Villars, professor of natural history of Grenoble, in a paper read before the national institute of France. He relates, that on the

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* Page 92.

† The Natural History of Ireland, by Dr. Gerard Boate, 1652, p. 63.

An Account of the Ground of a Water-Pit, bored at Amsterdam, presented to the Society by Mon. Huygens de Zulichem.

In the year 1605, the 15th of July, a water-pit was bored at Amsterdam, in the hospital of old men, 232 feet deep, (which is some 32 feet higher than the steeple of the old church there) and the ground was found as followeth:

		Feet.	
1	Stony and garden ground	7	
2	Fen and dairy (turf)	9	
3	Soft clay	9	
4	Sand	8	
5	Earth	4	
6	Clay	10	
7	Earth	4	
			51
8	Here followeth the sand on which most part of Amsterdam is founded	10	
9	Clay	2	
10	White sand	4	
11	Dry earth	5	
12	Turf bruised	1	
13	Sand	14	
14	Sandy clay	3	
15	Sand and clay mingled	5	
16	Sand and sea shells	4	
			48
17	After these ninety-nine feet, there is a couch of clean clay of	102	
18	Sand, in which the boring ended	31	
			133
			232 feet.

In the foregoing account, Mr. Huygens remarks, one thing is particularly observable, the occurrence of turf twice in the same boring, once immediately below the vegetable mould and gravel (stony ground), and again at the depth of seventy-two feet.

Various opinions have been adopted respecting the origin of peat, arising from the different appearances yielded by it in different situations. Many were of opinion, that it had obtained the form in which it now appears, when it originally came from the ledges, that the resemblance which the fossil trees bear to real pines is so great, that the peat-pits are called by the common people *keenen*, *kien-bomen*, or *kien-hout; kien* or *keen*, being the word which, in the German language, signifies pine.

In a similar manner he endeavours to account for the pine nuts or cones, which are found amongst the peat. If they be real pine-nuts, they must, he says, astonish every one; for although the pine is found in considerable numbers near to Breda, in Brabant, yet it is seldom found in any other part of Belgium.

He therefore, cannot think, although he cannot but admit, that, formerly, pines might have grown on these spots, and have been there overthrown and preserved, with their nuts, from putrefaction, by the including matter; that all those resinous balls, mixed with, and resembling those bodies, which he admits to be pine nuts, can possibly be real nuts; but he rather supposes them to be of the same nature with other bituminous masses, some of which, not unlike to walnuts, and others to eggs, are sometimes met with whilst digging. The only difference, he thinks, is that, in the seeming pine nuts, there is an admixture of sulphur and other things, which render them of a resinous nature, similar to the real cones.

Some also have attributed the formation of peat to the sinking of large floating islands, such as are now frequent in several parts of Holland, and such as have been known to have existed in very early ages; Seneca and Pliny having noticed the existence of a lake, on which was a floating island, near to Cutila, a town of the Sabines*.

Dr. Plot, in his Natural History of Staffordshire, relates, that at that period there were two floating islands on Kinson Pool, which were about twenty feet broad, and about thirty, or perhaps forty, feet long.

The utility of this substance, in those parts in which coal is not

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* Senecæ Natur. Quæst. lib. iii. cap. 16. Plin. lib. iii. cap. 12. lib. xxxi. cap. 2.

LETTER XI.

BITUMINOUS WOOD....SURTURBRAND OF ICELAND....BOVEY COAL OF ENGLAND.

PREVIOUSLY to offering, for examination, the opinion which I entertain, respecting the nature and the formation of peat, it will be proper to call your attention to some other substances; the origin of which has hitherto appeared to be equally doubtful. The necessity of furnishing you with the most material facts, which have been noticed, respecting these substances, before I attempt to communicate my ideas respecting the nature and the formation of peat, will, I trust, plainly appear, when I shew you the connection which appears to exist between it and those several substances; and when I also endeavour to demonstrate, on what principle the formation of all these substances depends.

The substance, with whose nature and properties I shall next endeavour to make you acquainted, is that which in Iceland is called *surturbrand*, and which, in this country, is chiefly known by the name of Bovey Coal.

The ligniform appearances, which bituminous substances sometimes bear, have been long known, and even the particular kind which we are now about to examine, has been noticed by some of the early writers in natural history. This substance, although possessing all the properties of bitumen, bears the distinctive marks of wood, but generally in the form of splinters or chips; or, if in larger masses, these are very capable of being divided into such fragments, even with a very slight force.

Theophrastus states, that there is found, in the mines of Scaptesylæ, a stone, in its external appearance something resembling rotfibres are very confused; the same fibres running straight, oblique, trnsverse, circular, and indeed in every possible direction, which, he observes, is never the case in vegetable wood.

Pillingen, who wrote expressly on the fossil wood of Meizlibizen, in Misnia, between Ziza and Altenberg, gives the following accurate description of it, entertaining the same opinion of its mineral origin with Schoockius: Whilst digging in a valley, at the foot of a mountain, near Altenberg, which had been deepened by frequent strong currents of rain water, flowing from this and the adjacent mountains; wonderful, he says, to behold, at a little distance from the surface, they found a substance like decayed wood, capable of being inflamed; bearing marks resembling those which result from an annual increase; and, in a word, so formed, by nature, that water was not more like to water, nor milk to milk, than this mineral wood, thus formed by nature, was to vegetable wood. The fibres of this wood, unlike to vegetable wood, were contorted and twisted in almost every direction, and it was generally found split into slices or chips. It was very light, except when containing pyrites, and its colour was a darkish brown. Whilst burning, it yielded a sulphureous or bituminous smell, and was thereby resolved into a light white earth, not unlike to amianthus, or plumose alum. White, hard, and exceedingly heavy pyrites, and particles of sulphur, he observes, were found very abundantly in this vein of fossil wood.

Beneath this layer of wood, the earth was strongly bituminous for nearly seven feet deep, and differed hardly in any thing from the wood itself, except that the fibres, which were distinguishable in the wood, were not here to be discovered of the same length: it was also much more frequently divided by clifts.

At first, on perceiving that this wood was so light as to swim on water; that it inflamed on being ignited; that it bore the marks of the long veins of wood; and, that it even had knots from which the boughs appeared to have grown; he concluded it to be real wood, the tree, but as hard as a bone, and in some as black as a coal. Similar to the Bovey Coal, its veins, instead of running straight, like the fibres of wood, were undulated and irregular, taking a variety of forms, and were only superficial; for, upon taking off one of the thin laminæ of which this fossil was composed, the veins underneath appeared in a different direction. This fossil, when first taken out of the earth, burnt like a bone; and consumed slowly in the fire, with a considerable smoke and disagreeable smell; but if dried, before it was burnt, the smell was more pleasing. Many of the pieces, he observes, are sprinkled with pyrites; and there exudes from some parts of it, a white bituminous substance, like rosin. Stelluti is convinced, that this ligniform matter is not of vegetable origin, but supposes it to be generated from a cretaceous earth, transforming itself into wood, by the assistance of sulphureous water, minerals, and subterraneous heat; a thick smoke, and sometimes even flames appearing, particularly in rainy weather.

Gassendus, in his Life of the illustrious Peireskius*, describes the fossil wood of Aqua Sparta, which had been just discovered. There were only found, he says, portions resembling trunks, but no vestiges of branches, knot, or roots; which yielded an argument, as it were, that woods might be generated and concreted in this form, and not, according to the vulgar, derived from wood overthrown and become petrified.

Professor Hollman, of Gottingen, presented to the royal society a paper, which appeared in the second part of the fifty-first volume of the Society's Transactions, with the title of *Montium quorundam prœaltorum, magna Ligni Copia quasi infarctorum, brevis Descriptio;* and in 1784 he republished it with some additions, at Göttingen, under the title of *Loci memorabilis, in quo ingens Ligni fossilis Copia reperitur, Descriptio.*

From these accounts, it appears that, near the city of Munden, and in that point of land which is washed by the rivers Werra and Fulda, as they unite to form one stream, several mountains successively arise. On the top of one of the loftiest of these, which is about 1150 parallel feet in height, is found a layer of mould of about a foot and an half, or two feet thick, under which is a stratum of yellowish clay, of two or three feet in thickness; and another, of a brown colour, considerably impregnated with alum and sulphur; and beneath these so large a quantity of fossil wood, as would almost exceed the belief of any one who had not seen it. This substance, called by those who dig it, fossil coal, the professor himself, at first doubted, whether it was really fossil wood or not; but it was not long before he became fully convinced, that it was indubitably of vegetable origin: he discovering not only the longitudinal, but with a glass, even the transverse fibres; and by a transverse fracture the marks of the wood's annual increase. This wood existed almost entirely in small fragments, laying very compactly on each other, each fragment being divided by numerous fissures, so as to render it difficult to form any opinion of the real size of the trunks, or branches, which they originally formed. Nor, during all the time which they had dug for this wood, had they ever met with any of length sufficient to show the branches; neither had they discovered any leaves, or any fragment still retaining its circular form. The professor, however, himself saw a trunk with a portion of the roots still adhering, fully impregnated with pyrites. On another piece he observed the traces of leaves sufficiently evident. Frequently, he remarks, are pieces of wood found, not merely almost surrounded with pyrites, but so fully impregnated with them, that although the situation and form of the several parts of the wood are exactly preserved, its conversion into pyrites appears to be entirely complete. Some of the specimens of this kind are described as being most elegant in their appearance, but unfortunately soon fall into pieces when exposed to the air; their surface first, as it were, exuding sulphur and alum in a pulverulent form. To prevent this decomposition and destruction of his more valuable specimens, he adopted the practice of washing off the salts from them, by two or three times in the day pouring boiling water over them; and thus he had preserved some for the space of three or four years.

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* Vita illustris Peireskii, lib. v. 1637.

The quantity of this fossil wood appears to have been truly prodigious. The stratum, of which we have hitherto spoken, was about twenty feet in depth, the bottom of it resting on a stratum of stone; about a foot in thickness. On piercing this, another stratum of fossil wood was found: to discover the depth of which several attempts were made; but although the borers passed to the depth of thirty feet, they did not reach to the bottom of this stratum. Hence it was only ascertained, that the fossil wood was at least fifty feet deep; since they were unable to determine to how much greater a depth the stratum reached. A difference was observable in the two strata, which merits our particular notice: the fossil wood contained in the upper stratum, was of a light brown colour; but that in the inferior stratum, was of a much darker brown, verging upon black.

The earth, which lay over the fossil wood, not only had the same brown colour for more than half a foot in thickness, but was impregnated with similar sulphureous, and aluminous particles, and even yielded almost as good fuel.

Taking advantage of a passage which had been dug into the body of fossil wood, the professor passed nearly two hundred feet in length within it, so that the roof, floor, and sides of the place, in which he stood, were entirely composed, of what he esteemed, a mass of vegetable ruins. Here the water, which had insinuated itself in the top of the mountain, was found dripping through the roof; and sulphureous and aluminous matter were found to exist, in an equal proportion, with that which pervaded the other parts of this mass. Between the fossil wood was seen, in some places, a vein of hard, blackish bitumen, possessing almost the hardness and splendor of jet. This vein of indurated bitumen, was a foot, and even more, in thickness. The professor saw, also, some specimens of marble, from this mountain, containing small bivalves; and obtained, from the same mountain, two marine shells, the one in a petrified, and the other in a pirytified state; as well as a most elegant serrated tooth, resembling those of the shark, which, with its base, measured three inches and an half in height. Hence he concludes that this mountain must, at some former period, have been covered by the sea.

The indefatigable Rosinus, who also visited this mountain, relates, that a large quantity of potter's clay is dug here, and frequently with it fragments of wood, with black bitumen, and sometimes pyrites. He also describes hard flint stones, containing charcoal; and reeds, or at least their impressions, which, with an abundance of marine remains, were dug out of the bowels of the earth, in the same mountain.

Professor Hollman also gives us, in the same work, a particular description of the circumstances, most worthy of notice, which he perceived in the examination of a mountain, near Altendorff, so famous for its salt-works, on the borders of Hesse. The height of this mountain appears to be about 2500 feet, exceeding that of the mountain, just described, in the neighbourhood of Munden, full seven hundred feet. His astonishment was here still more excited, than when contemplating the wonders of the former mountain. Under an immense roof, formed by a vast stratum of stone, which was from eighty to an hundred and forty yards in thickness, was a vein of fossil coal, in most places of upwards of twelve feet in depth, which had long been dug to supply fuel for the neighbouring salt-works, and of which an incalculable quantity still remained. This fossil coal agreed almost in every respect with the small vein of bitumen he had observed in the interior passages, which had been dug in the mass of fossil wood, in the former mountain: possessing, like it, the brightness and hardness of jet. In proportion also, as the fossil wood lay near to its superincumbent stratum of fossil coal, it was evidently the more impregnated with bitumen; possessing a darker colour and a greater degree of compactness. That which was at a greater distance from the vein of coal, being situated still lower, differing not much in its colour, and general qualities and appearance, from common decayed wood. It is a circumstance worthy of particular attention, that the stratum of stone, at its inferior surface, was so exactly adapted to the upper surface of the stratum of coal, as to give the idea of a fluid matter having been poured over the subjacent hard and coherent stratum. In the same manner, also, did the lower surface of the fossil coal apply to the superior surface of the fossil wood.

In the same volume of the Philosophical Transactions* which contains Professor Hollman's more abridged account of this fossil wood, is also a paper by the Rev. Dr. Jeremiah Milles, entitled "Remarks on the *Bovey Coal.*" Dr. Milles observing, that the fossil wood described by Professor Hollman corresponded in many particulars with some strata, discovered about fifteen years before, in Devonshire, and which he was satisfied were not of vegetable origin; concluded therefore, that the substance described by Professor Hollman, likewise, was not wood. The account of this fossil, the Bovey Coal, as given by Dr. Milles, is highly interesting, and is therefore here given in his own words.

"It is found on a common surrounded with hills, called Bovey Heathfield, in the parish of South Bovey, thirteen miles south-west of Exeter, and three miles west of Chudleigh. The uppermost of these strata rises within a foot of the surface, under a sharp white sand, intermixed with an ash coloured clay, and underlies to the south about twenty inches in a fathom.

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* Philos. Trans. vol. li. part 2, p. 534.

"The perpendicular thickness of these strata, including the beds of clay, with which they are intermixed, is about seventy feet. There are about six of each, and are found to continue eastward, in an uninterrupted course, to the village of Little Bovey, a mile distant; and probably extend much further. The strata of coal, near the surface, are from eighteen inches to four feet thick; and are separated by beds of a brownish clay, nearly of the same dimensions, but diminishing in thickness downwards, in proportion as the strata of coal grow larger; and both are observed to be of a more compact and solid substance, in the lower beds. The lowermost stratum of coal is sixteen feet thick; it lies on a bed of clay, under which is a sharp green sand, seventeen feet thick, and under that a bed of hard coarse clay, into which they have bored, but have found no coal. From the sand arises a spring of clear blue water, which the miners call *mundic water*, and a water of the same kind, trickling through the crevices of the coal, tinges the outside of it with a blue cast.

"Beneath this was an equal, if not a greater, quantity of fossil wood, with that which existed in the mountain already mentioned. With that wood it appeared, in general, to agree pretty much in its nature and appearance: it however did not seem to be accompanied by so much mineral salts as the other.

"Some small, and narrow veins of coal, are found intermixed with, and shooting through, the beds of clay; bearing impressions, like those of reeds and grass; and very similar to those which are found on the top of coal mines. The clay also, at least that part of it which lies nearest the coal, seems to partake of its nature, having somewhat of a laminous texture; and being, in a small degree, inflammable. Amongst this clay, but adhering to the veins of coal, are found lumps of a bright yellow loam, extremely light, and so saturated with petroleum, that they burn like sealing wax, emitting a very agreeable and aromatic scent.

"Though the substance and quality of this coal, in its several strata, are much alike, and it is all indiscriminately used for the same purposes; yet there is some difference in the colour, form, and texture of the several veins. The exterior parts, which lie nearest to the clay, have a greater mixture of earth, and are generally of a dark brown, or chocolate colour; some of them appear like a mass of coal and earth mixed; others have a laminous texture, but the laminæ run in such oblique, waving, and undulating forms, that they bear a strong resemblance to the roots of trees, of which kind, the Doctor says, I have seen some specimens from Lough Neagh, in Ireland, which seem to be the same sort of fossil.

"There are other veins of this coal, which lie more in the centre of these strata, and abound most in the lowest and thickest bed, the substance of which is more compact and solid: these are as black, and almost as heavy, as pit coal; they do not so easily divide into laminæ, and seem to be more strongly impregnated with bitumen: these are distinguished by the name of *stone coals*, and the fire of them is more strong and lasting than that of other veins.

"But the most remarkable and curious vein, in these strata, is that which they call the *wood-coal*, or *board-coal*, from the resemblance which the pieces have to the grain of deal boards. It is sometimes of a chocolate colour, and sometimes of a shining black. The former sort seems to be less impregnated with bitumen, is not solid and heavy, as the latter, and has more the appearance of wood. It lies in straight and even veins, and is frequently dug in pieces, of three or four feet long, and, with proper care, might be taken out of a much greater length. Other pieces of the same kind are found lying upon them, in all directions, but without the least intermixture of earth, and without any interstices, except some small crevices, by which the pieces are divided from each other, in all directions. When it is first dug, and moist, the thin pieces of it will bend like horn; but when dry, it loses all its elasticity, and becomes short and crisp. At all times, it is easily to be separated into very thin laminæ, or splinters; especially if it lie exposed any time to the heat of the sun; which, like the fire, makes it crackle, separate, and fall to pieces.

"The texture of this fossil consists of a number of laminæ, or very thin plates, lying upon each other horizontally, in which small protuberances sometimes appear, like the knots of trees; but upon examination, they are only mineral nuclei, which occasion this interruption in the course of the laminæ: and pieces of spar have been sometimes found in the middle of this wood coal. Though the texture of this coal is laminated, yet it does not appear to have any of those fibrous intersections, which are observed in the grains of all wood. This coal easily breaks transversely, and the separated parts, instead of being rugged and uneven, are generally smooth and shining, in which even the course of the laminæ is hardly discernible.

"When this coal is put into the fire, it crackles, and separates into laminæ, as the cannel coal does, into irregular pieces; burns for some time, with a heavy flame; becomes red hot, and gradually consumes to light white ashes. Though the transverse crevices, made in it by the fire, give it the external appearance of a wooden brand, yet, if quenched when red hot, the unconsumed part does not look like charcoal, but seems to be almost as smooth and solid, as when first put into the fire.

"The thick heavy smoke, which arises from this coal when burnt, is very fœtid and disagreeable: entirely different from that aromatic scent of the bituminous loam, which is found adhering to it; but much resembling that of the asphaltum or the bitumen of the Dead Sea. The most shining and solid pieces of this coal, have not the least degree of electrical attraction."

Notwithstanding the resemblance, which this fossil bears to wood, especially when viewed in detached pieces; yet the doctor was of opinion, that he was able to prove that it was not of a vegetable, but of a mineral origin.

The observations on which he founded this opinion, will require, however, here to be mentioned only in a cursory manner. His first objection is derived from its quantity; since it extends here to the depth of seventy feet, and in that of Munden, as we have seen, they had bored to the depth of fifty feet, without discovering its bottom: he thinking, that there could have been no imaginable cause in nature, which could bring together such a mass of fossil wood, as is found in this and similar strata.

Fossil trees, he remarks, are generally discovered in morasses and soft ground; where they have either buried themselves by their own weight, or been overwhelmed by some accidental cause: but the Bovey Coal is found in a dry soil, intermixed with clay and sand; and by its regular course and continuance, he thinks, carries the most undoubted marks of never having been disturbed since its original formation. Fossil trees, he likewise observes, preserve their form and size, their length and roundness, their branches and roots, their fibrous texture and strength; and are either found entire, or in such large pieces, that there is no room to doubt of their nature; since the very species of wood is frequently distinguishable: whereas the Bovey Coal comes out only in flat pieces of a few feet long, like the splinters of large masts; and on them we discover no signs of roots, branches, or bark; no round pieces, or concentric circles, which distinguish the annual growth of trees: the laminæ, which have the appearance of wood, being always horizontal, according to the situation of the pieces in the strata. Again, he observes, if the basis or matrix of this fossil were wood, it would acquire, by being impregnated with bitumen, a greater degree of inflammability; whereas it neither kindles, nor consumes so fast as wood.

The inflammability, and laminated texture, of this fossil, which have been the circumstances leading to the supposition, of its being of vegetable origin, may be accounted for, in the opinion of Dr. Milles, from the nature of its principles, and their disposition, when united, to assume certain forms.

It must not be omitted to remark, that the strata of Bovey accord very much with those of Munden and Allendorf; the stratum of wood, both in Germany and England, being accompanied with clays, boles, and sand. At Bovey, there also being beds of very fine pipe-clay, of which great quantities used to be sent to Liverpool.

The fossil wood of Iceland, described by Wormius*, appears to be also of this kind. The *surturbrand*, or *sortebrande*, according to his account, being a laminated substance, generally black, but sometimes only of a dark brown colour. When first dug out of the earth, it is capable of being bent like a twig; but it is brittle, when dry. It consists of oblique fibres, frequently interrupted by knots, like the roots of a great tree, which are full of crevices. This stratum is found, he says, some yards under the earth, in a mountain so high and perpendicular, that those only who have been accustomed to climb such precipices, can venture to dig for it. There is no appearance, that trees ever grew where this fossil is found; Wormius, however, concludes them to be roots of trees turned black, by a subterraneous vitriolic juice.

Horrebow, in his History of Iceland†, describes the *sortebrand*, or black-brand, as an extraordinary sort of wood, very hard, heavy, and black, like ebony; which is found deep in the ground, in broad, thin, and pretty large, pannels, or leaves; fit for a moderate sized table. It is, he says, generally wavy and undulated; and found in the rocks or great stones, wedged, as it were, close in.

But the most satisfactory account we have had of the fossil wood of Iceland, is given by Dr. Uno Von Troil, from the observations he made during a voyage to that island, with Sir Joseph Banks, Dr. Solander, and Dr. Lind, in the year 1772.

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* Mus. Wormian. lib. ii. cap. 16.

† The Natural History of Iceland, by Horrebow, p. 33.

The surturbrand, he says, is evidently wood, not quite petrified, but indurated; which drops asunder as soon as it comes into the air, but keeps well in water, and never rots: it gives a bright, though weak flame, and a great deal of heat, and yields a sourish, though not unwholesome smell.

The smiths prefer it to sea coal, because it does not so soon waste the iron. The Icelanders make a powder of it, which they make use of to preserve their clothes from moths: they likewise apply it externally against the cholic. The doctor says, I have seen tea-cups, plates, &c. in Copenhagen, made of surturbrand, which takes a fine polish. It is found in many parts of Iceland, generally in the mountains, in horizontal beds; sometimes more than one bed is to be met with, as in the mountain of Lack, in Bardestrand, where four strata of surturbrand are found, alternately with different kinds of stone.

He brought a large piece of it with him to Sweden, in which there were evident marks of branches, the circles of the annual growth of the wood*.

The same sort of fossil wood is described by Wormius as found in the island of Faro. It does not, he says, readily take fire, but has a splendor like jet. It is found in the crevices of the rocks, and is taken out in laminæ, or splinters, of three or four inches thick.

Scheuchzer mentions a stratum of fossil wood, which he saw near Thun, in Switzerland, which was laying under several strata of flints, clay, and ash-coloured marle. Of this wood, he says, some parts, on exposure to the air, grew hard, and others broke to pieces. He noticed also, that the trunks and branches of this fossil wood were not round, but compressed; yet, in some places, clothed with their bark, and here and there adorned with their leaves. The wood was inflammable, making a strong fire, and serving instead of fossil coals.

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* Letters on Iceland, by Dr. Uno Von Troil, D.D. p. 42.

Dr. Plott in his History of Oxfordshire, relates, that the scarcity of firing, in some parts of that county, has induced the people to burn a sort of black substance, of a grain somewhat like rotten wood, half burnt; partaking also of a mineral nature, and therefore called by authors *metallophyton*, or *lignum fossile*. Put into water, it will not swim; and into fire, it consumes but slowly, and sends forth very unpleasant fumes. A vein of it, at Ducklington, looked like wood; yet broken, shewed a smooth and shining superficies, not unlike to stone pitch; and put into the fire has not near so ill a smell. The doctor, who fully believed in the frolics of the stone-forming archæus, says, as to the substance of *lignum fossile*, it is thought to be a cretaceous earth, turned to what it is by subterraneous heats; for that it was never formerly wood, notwithstanding its specious and outward likeness, is plain from its never being found with roots or boughs, or any other signs of wood *.

Dr. Morton, who likewise did not believe in the subterranean change and preservation of organised matter, describes two or three species of this metallophyton †, one of which, he says, is of a dark colour, and has a grain; for in one direction (which is usually according to the length of the pieces) it cleaves or parts pretty readily into plates and splinters; the other way it snaps into shorter pieces, and will not cleave at all. There is another sort, which does not so readily part into flakes. None of these are found in any large masses. They are all, more or less, of a glossy black, and have a density or smoothness within, like that of bitumen, or jet. In that also they resemble, as he remarks, the true bitumen, or pissaphalton. They are not so firm and hard as the common coal, and are much more brittle than cannel coal, or jet. They likewise all of them agree, pretty nearly, in the same properties. In water they sink; they are all inflammable, but consume slowly in the fire; emitting a somewhat unpleasant fume, not unlike that of bitumen, only fainter.

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* The Natural History of Oxfordshire, by Dr. Plott, p. 65.

† The Natural History of Northamptonshire, by Dr. Morton, p. 121.

A coal is found in the cliffs, near the castle, in the isle of Portland, which has been thought to be similar to the coal which we have been hitherto considering. The Kimeridge Coal, so called from the place where it is dug, and which appears in most of the cliffs of the isle of Purbeck, from St. Aldhelm's Chapel to East Lulworth, and at Ovington, opposite to that part of Portland where the coal is dug, is also supposed to be of the same kind. But on reviewing the description of these coals, which are said to be very hard, and to shiver into pieces like slate, when exposed to the air, I am more disposed to suspect, that this fossil was rather a bituminous schistus, than a species of the Bovey Coal.

Hoffman appears to describe a similar species of fossil wood, found in the neighburhood of Fischausen, &c. where they dig for amber. The upper stratum is sand, under it a bed of clay, and then a woody stratum, consisting of a substance like old wood, but inflammable; under this, he says, was a vitriolic mineral; and lastly a bed of sand, in which a great quantity of amber was found*.

Of this kind too, very probably, was the fossil wood described by Cæsalpinus, as found in the kingdom of Naples, in a hill near the city of St. John. Part of this, he says, is formed of an incrusted inflammable stone, of a brown or ash colour, resembling decayed wood. This, he says, the inhabitants employ for their fires. As it burns it becomes black, like half-burnt wood, and at length passes into cinders.

Mr. Fontaine discovered a subterraneous forest, at the bottom of the chain of mountains between Lyons and Strasburgh. Some of these pieces of wood still retaining their ligneous form, though actually a vegetable coal.

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* Observationes Physico-Chemicales, lib. ii. p. 199.

In the island of Pago, one of the islands in the Adriatic, is a large internal salt water lake, on the bank of which, is a mine of fossil coal, which is, most probably, similar with the Bovey Coal. It is described, by the Abbé Fortis*, as still preserving the distinguishable appearance of wood; but being of so bad a quality, that no use can be made of it except in a case of the greatest necessity.

Mr. Brand informs us, that Sir Joseph Banks, Bart. and President of the Royal Society, so eminent for his knowledge in natural history, favoured him with the inspection of a large specimen of fossil coal found in Iceland, in strata of considerable thickness, and at great depths; which seemed to exhibit a substantial proof that coal originally was wood. Sir Joseph has preserved several trunks of it, each of which is flattened, possibly by the weight of super-incumbent strata; so that instead of being cylindrical, as the body or root of a tree naturally is, it is flat. Some of them are more, and some less woody; one is a fair plank of wood. As the woody ones are the greatest curiosities, they are sent in preference. The specimen described, appears to have been the root of a small tree, with the bark still adhering and remaining on the greatest part of it. In the lower part, however, the transformation had proceeded further than at the top, so that it was real coal, while the top was actual wood †.

Count Stolberg relates, that bituminous wood may be found almost every where, at a certain depth, on the western part of Orange Nassau; in about 200 fathoms west of which is an immense quarry of iron stone.

A coal, resembling the Bovey Coal, has also, according to the account of Mr. Barrow, in his Travels into Southern Africa, been found at the Cape of Good Hope.

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* Travels into Dalmatia, by Abbé Alberto Fortis, p. 503.

† The History and Antiquities of the Town and County of the Town of Newcastle-upon-Tyne, by John Brand, M.A. 1789.

Pillingen informs us, that upon distilling the fossil wood of Meizlibizen, he obtained from it, as well as from the bituminous earth, which accompanied it, nothing which appeared to be derived from vegetable matter. With a gentle heat, on sand, a water came over, tasting of bitumen, and a limpid and penetrating oil, like oil of amber. On increasing the heat, he obtained a more fœtid, thick, and sulphurous oil; with a slightly acid, but pungently smelling water. By still farther increasing the heat, he obtained a most thick, black, stinking oil, with a turbid sulphurous water, having an acid and disagreeable taste. With an intense naked fire, a light brown, flocculent, sulphurous, or rather, he says, a saline bitter sublimate arose; leaving a hard clinkery matter at the bottom of the retort; from every hundred pounds of which, he assures us, he was able to obtain nearly an ounce and a half of the purest silver.

Dr. Milles also subjected the Bovey Coal to analysis, by which, he says, if any doubt could remain of its being a mineral substance, it must be completely removed.

From one pound of Bovey Coal, of the woody kind, he obtained on sand, four ounces and a half of water, of a bituminous smell and taste; nearly four ounces of a turbid, whitish, bituminous liquor, of an intolerable fœtid smell, and extremely pungent to the tongue; and about two drachms of a heavy bituminous matter, which would not mix with the former liquor, but sunk entirely to the bottom, without leaving any light oil floating on the bituminous liquor. There remained in the retort about seven ounces of a very black powder, which had the same bituminous smell, and not very heavy; some of which being put on a red hot iron, emitted a little smoke, but no flame. The ashes of this fossil yielded no salt on being boiled in water.

Salt of hartshorn manifested no particular effect with the water which first came over; but with the bituminous liquor, allowed to stand until it had become clear, it caused a considerable ebullition; the mixture becoming foul and red, and in a few days it became thickened and of the colour of tar; the surface of it, as well as the sides of the phial, being covered with a bituminous pellicle. By exposing the black gritty powder, in a retort, to a red heat for two hours, the neck of the retort became thinly incrusted with something that resembled a saline concrete, but which he found to be only a bituminous matter.

The black powdery residuum being kept red hot in a close vessel, for a longer time than he thinks would be sufficient to have reduced an equal quantity of vegetable charcoal, still emitted a thick heavy smoke, when sprinkled on a red hot iron; and upon farther exposure to heat, in an open vessel, an astringent mineral salt was left, but no saline matter, which, he thinks, together with the bituminous nature of its products, affords a sufficient proof of this fossil wood differing from all known wood, belonging to the vegetable kingdom, and of its being an actual mineral substance.

I cannot close this letter without, in justice to Professor Hollman, noticing the hard fate of his useful observations, or rather discoveries, on this subject. In the year 1753, he delivered to the Royal Society of Gottingen, a most excellent dissertation on the origin of marine, and other foreign substances, contained in the earth*; which appeared in the third volume of the Society's Transactions. Another dissertation, the one from which we have derived so much information†, was also decreed to appear in the fifth volume of the same work; but foreseeing, what actually happened, that the latter paper would be excluded from public view, in consequence of some disputes of a part of the society with the publisher of the work, he providently resolved to transmit an abridged copy of his last paper to the Royal Society of London, who did him the justice to publish it in their Transactions. In the same volume, were communicated to the public, the Remarks on the Bovey Coal, by Dr. Jeremiah Milles, which I have already so fully noticed; and in this paper the opinion of Professor Hollman, respecting the nature of this fossil wood, was, as you have seen, disputed, and its mineral origin asserted. The Professor, however, thoroughly convinced of the propriety of the opinion he had adopted, sent a paper which he supposed would confirm the arguments he had employed in his former paper; but in consequence, as the Professor supposes, of its not coming to hand, this paper was never, in any way, noticed. When he republished his two first papers, at Gottingen, in the year 1784, he, therefore, joined to them two additional papers: one of which was the paper which had been sent for, but had not appeared in, the Philosophical Transactions; in which he fully evinced the truth, and propriety of his former observations; and the other contained some very judicious remarks on the hypothesis of the gradual change of a cretaceous earth into wood, which had been advanced by Stelluti; and by which Dr. Milles had endeavoured to support his hypothesis of the mineral origin of this fossil wood.

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* De Corporum marinorum, aliorumque peregrinorum, in Terra continente, Origine.

† Loci memorabilis, in quo ingens Ligni fossilis Copia reperitur, Descriptio.

Thus was the first original and complete copy of this author's ingenious paper, on this subject, kept for nearly twenty years from the eye of the public; and the abridged copy, governed by a fate not less severe, made its appearance, under the most unfavourable auspices; since, being published in the same volume of the Philosophical Transactions of the Royal Society of London which contained a very laboured attempt at refutation of the very opinion he had adopted, it appears to have obtained but little notice. The answer to Dr. Milles's paper, not appearing in the Philosophical Transactions, it seemed that the Professor, subdued by his superior arguments, had left the field to Dr. Milles, and had totally relinquished the opinions he had before advanced. Thus the state of the controversy existed for upwards of twenty years, when Professor Hollman finding that his paper had not been published in the Philosophical Transactions of London, he published it himself, with additional arguments, undeniably proving the truth of his first opinions, and the mistake of his opponent.

In justice to the conductors of the Philosophical Transactions, I must inform you, that a diligent examination of the papers of the Royal Society, contained in the library of the British Museum, has induced me to believe, that Dr. Hollman's paper never came to hand; since it is not to be found in its place: nor does there appear to be any notice of its having been received.

I am pleased to find your last letter dated from Exeter, since it suggests to me, that by your taking Bovey in your way, you will be able to obtain for me some account of the Bovey Coal, on the spot. This, I am confident, you will obtain, by applying to J. Templer, Esq. on whose estate I believe some part of this fossil is plentifully found.

Yours, &c.

LETTER XII.

IN ANSWER, FROM BOVEY.

PRESENT STATE OF THE COAL-PIT AT BOVEY....STRATA, &c.

OUR little party are indebted to your letter of introduction to Mr. Templer, for a considerable degree of pleasure; and that, notwithstanding that gentleman was obliged to be absent, in a distant part of the country, at the time we paid our visit to Bovey. His polite attention had prepared for us every gratification which the kindest hospitality could direct: and careful that, notwithstanding his absence, the object of our visit should be obtained, as completely as possible, he had requested a neighbouring gentleman to conduct us to the pit, and furnish us with that information which you wished to acquire. This gentleman, Robert Scammell, Esq. of Bovey, with the greatest affability, accompanied us to the spot where this extraordinary substance is found; which we found deposited in layers, to a considerable depth, and extending——but it is useless to give you the observations which I made, since, to secure to you the most satisfactory account, I prevailed on our obliging and scientific conductor to supply you with that intelligence, which his repeated examinations of this spot, made effectual by his scientific mode of conducting them, must render valuable.

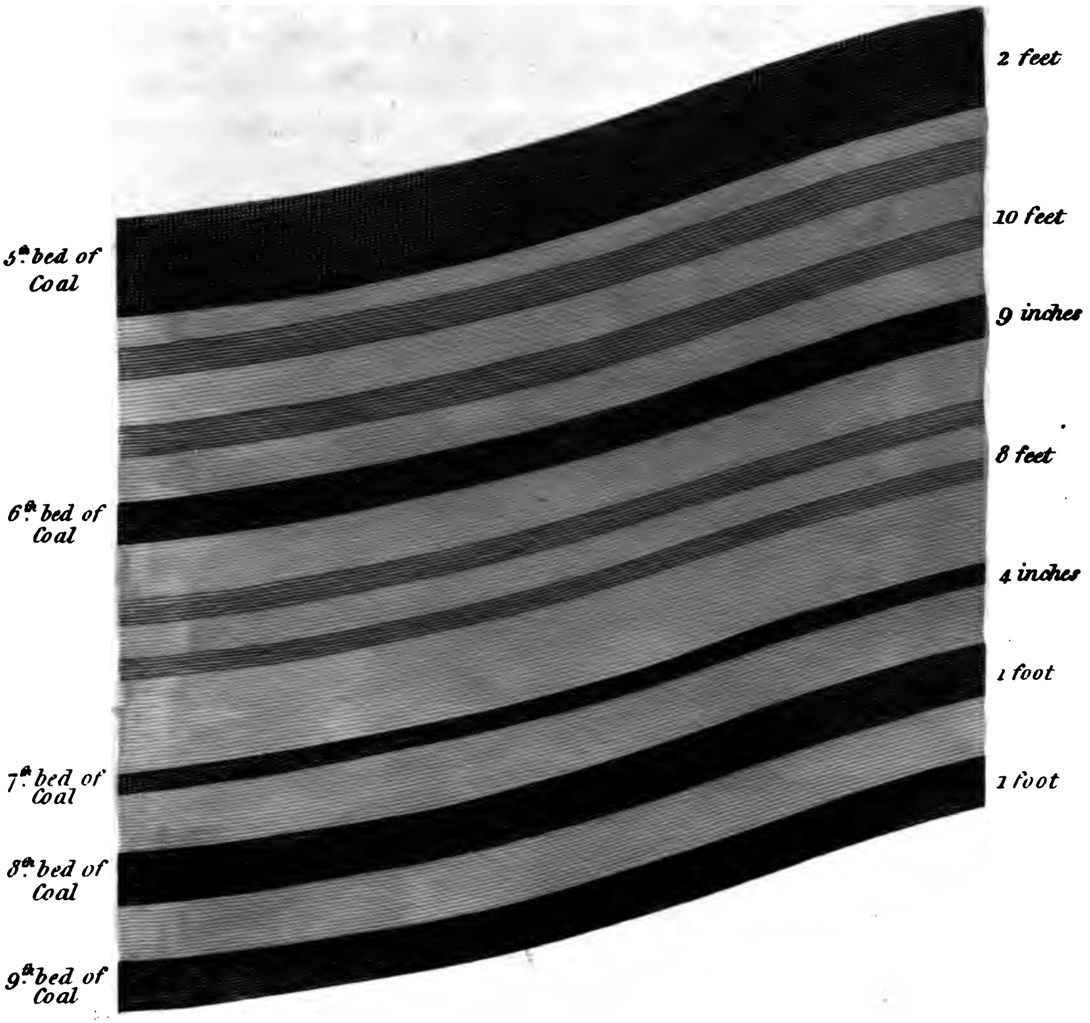
Particulars respecting Bovey Coal, dug at Bovey, near Chudleigh, Devonshire—by Robert Scammell, Esq. of Bovey.

BOVEY COAL.

THE strata covering the coal, consist of earth of the argillaceous genus, the *argilla apyra* of Waller; the *pfeiffen erde* of the Ger-

P. 177.

Section of part of the Strata of Coal &c. at Bovey.



The darkest shade denotes the Strata from which the Coal is procured, the lightest, the argillaceous Strata, & the intermediate, an inferior kind of Coal.

mans. With regard to their depth, a more accurate idea may be formed from the annexed sketch; remarking, in this place, the lower the coal, the less the depth of the incumbent strata. The depth of the coal strata is various, as the following sketch will elucidate. The following table shows the depth of the several coal beds which are worked.

Strata	Ft.	In.	Strata.	Ft.	In.
No. 1	1	0	No. 11	0	6
2	0	18	12	2	0
3	2	0	13	1	2
4	0	18	14	1	3
5	2	0	The great bed in four floors, No. 15,	2	0
6	0	9		1	2
7	0	4		1	4
8	1	0		1	0
9	1	0	16 The little bed	1	0
10	1	9	17 The last bed	2	7

The lower coal strata furnish the best and strongest substance for burning. The shaft, from the grass to the bottom of the last coal stratum, is seventy-five feet deep. It has been bored thirty-three feet still deeper, but nothing was discovered but a kind of muddy clay, intermixed with sand. The disposition of the strata is displayed by their method of working: they begin on the top, and clear away to the distance of eight or ten fathoms, and work down, in a perpendicular direction, through the various strata, to the bottom of the shaft; then recommence their operations, &c.

The direction of the strata is from north to south; the inclination or dip tending to the latter. This inclination is computed to be about one foot in six; the leading part is from east to west. The northern part reaches to the surface, within an hundred yards of the shaft, where it is cut off by a bed of sand; to what depth the southern extremity reaches has not been, and possibly cannot be, ascertained; however, it has been found to extend a quarter of a mile. The eastern portion has been clearly found to extend upwards of seven miles, by the experiment of repeated boring; whilst the western has not, as yet, been traced further than two miles.

The whole area, including the working, from the first period to the present time, amounts to ten acres.

The Bovey Coal is now used for supplying the steam-engine, for burning lime, and, occasionally, for giving the earthen-ware its first burning; it is not now used for domestic purposes, the sulphurous gas it emits being, not only extremely disagreeable, but injurious to the health of the inhabitants. It has been said, that exposure to the influence of the sun and atmosphere, for some months, has deprived it of this pernicious quality; but this is not warranted by experience; even seven years has only lessened, but by no means destroyed it intirely. It certainly undergoes considerable decomposition; the different laminæ cracking and peeling off, from the evaporation of the contained moisture; it then weighing considerably lighter.

The coal has some peculiarities, with respect to its appearance. From this circumstance, the workmen have divided it into three species or varieties, which they call *stone coal*, *board coal*, and *knotty coal*. Some portions bear evidently the effect of fire, and resemble, in every respect, as to external appearance and touch, the common charcoal.

From every observation and inquiry I have made, it does not appear, that any substance of a vegetable form has ever been discovered, either in the coal strata or incumbent strata: no leaves, pine-nuts, or any thing of a similar nature.

Solid bitumen has often been met with, both in the coal and argillaceous strata; and it has been remarked, that the coal, taken up after this substance has been found, is always of good quality. A species of spar, the *spath adamantin* of the French, has been sometimes, though rarely, found in the middle of a portion of the coal. The iron *pyrites* is met with very frequently. There are springs impregnated with ferruginous matter, depositing an ochre, which is sometimes used in the pottery.

It appears, upon enquiry, that the space of time from the Bovey Coal being first worked, to the present, is a period of upwards of ninety years. The annexed sketch shews the arrangement of strata. The white denotes the argillaceous strata, the black points out the strata, from which the coal is procured; and the lightly shaded are strata containing an inferior kind of coal, not worth taking up.

OBSERVATIONS.

The spot now worked for the Bovey Coal, is situated in low boggy ground, which extends several miles: it is said to be the lowest in the county, but this is an assertion not true. To the south of the shaft, about a quarter of a mile, is a bog, from which has been taken (several feet below the surface) many trees of the fir kind; several eighteen inches in diameter, together with pine-nuts, but no traces of coal.

This is the account with which our friendly guide favoured us, and to us it has proved highly gratifying; since we have been thereby enabled to compare the present state of this curious spot, with that in which it existed near fifty years ago, according to the description given by Dr. Milles. To you, for the same reason, it cannot but prove particularly acceptable.

Yours, &c.

LETTER XIII.

BITUMENS....PARTICULAR KINDS DESCRIBED....KNOWN TO WRITERS OF THE HIGHEST ANTIQUITY....HISTORY OF NAPHTHA, PETROLEUM, AND ASPHALTUM, FROM THE MORE ANCIENT NATURALISTS.

THE substances, the nature of which next require our consideration, are those which are generally denominated bitumens. Naphtha, petroleum, mineral tar, mineral pitch or maltha, asphalt, elastic bitumen, jet, mineral coal, amber, and mineral tallow, are the different substances which, by general consent, are placed in this class.

The propriety of dwelling on the history of these substances, in a work devoted to secondary fossils, may not, perhaps, at first sight, appear; but when their origin is more closely traced, and when they are considered, in connection with the other substances, which appear to be derived from the same origin; not only will their importance be perceived, but their right to be considered, themselves, as secondary fossils, will, I trust, be evident.

Bitumen is a substance of a peculiar kind, seeming to partake both of an oily and resinous nature, and is found either buried in, or proceeding from, different parts of the earth, in different states of consistence. The different degrees of consistence, as well as the variety of colour, which the more simple of these substances possess, according to the valuable observations of Mr. Hatchett, depend on certain changes, which have taken place in the same substance. We will first notice the more simple states in which these substances exist.

NAPHTHA *(oleum terræ)*, which Mr. Hatchett considers as bitumen in its greatest purity, is a very thin, yellowish, but sometimes colourless oil, of a strong, but not disagreeable odour. It is so highly inflammable, that it catches fire, even on the approach of flame; burning freely, with a large white flame, and leaving scarcely any residuum. Its specific gravity may be taken at .8475 from Brisson. It does not freeze at 0°. Fahrenheit. It is insoluble in alcohol. By exposure to the air, it becomes yellow, and then brown; and at the same time acquires a greater degree of consistency; passing into petroleum. It is found in great abundance in Persia; it sometimes is found on the surface of the waters of springs, and sometimes issuing from certain strata.

Petroleum is a tenacious, brown fluid, which, according to the length of its exposure to the air, increases in thickness, and in darkness of colour; until it acquires nearly the viscidity of common tar: its smell, at the same time, becoming less pleasant. In this state, although highly inflammable, it burns, with a flame less clear and white, yielding a soot, and leaving a small quantity of coaly residuum. Specific gravity, .8783, Brisson. It is also found in Persia, and likewise in many parts of Europe.

Mountain or Mineral Tar is the name given to this substance, when it has acquired the consistency and colour of common tar. It emits a strong bituminous smell, on being burnt. Specific gravity, 1.1.

Mineral Pitch and Maltha, are terms employed to mark the different higher degrees of colour and consistency, which this substance possesses in its further inspissation. Whilst so soft as to possess some degree of tenacity, it is called *mineral pitch*; but when it has become almost black, and so hard as neither to stain nor adhere to the fingers, it is termed *maltha*. Its specific gravity varies with its degrees of induration, and with the quantity of earth it contains.

Asphaltum appears to be the same substance, in its highest degree of induration. It is a light, brittle, brown or blackish substance; shewing, when broken, a conchoidal fracture, with a glassy lustre. It manifests a bituminous odour, when rubbed or heated. It melts easily, and is very inflammable; burning away, when pure, without leaving any ashes. Its specific gravity, according to Kirwan, is from 1.07 to 1.65.

Asphaltum has been spoken of by Dioscorides, and other writers before him, by the name of *pissasphaltum*; this name, according to Pliny[*], being applied to it, on account of its being mixed with common pitch. Agricola[†], however, denies this, and contends, that it derives this name from the circumstance of its odour so much resembling pitch.

MINERAL CAOUTCHOUC, or ELASTIC BITUMEN, appears to differ from mineral pitch, merely in the degree of elasticity which it possesses; which seems to be the consequence of the confinement of air, or of some other elastic fluid, in its interstitial cavities.

Having thus furnished you with the most obvious characters of bitumen in its simpler states, I shall proceed to shew you, that at very remote periods, and in various parts of the world, the peculiar appearance and properties of bitumen procured it a considerable degree of attention.

You will not only find, that it furnished the early writers in natural history with an interesting subject of inquiry, but that it was known to mankind, as a substance capable of being applied to various economical uses, in the earliest ages of which we possess any authentic record.

Noah, we are told, coated over the ark, within and without, with pitch[‡]. The builders of the tower of Babel employed some bituminous matter as a cement; "*they had brick for stone, and slime had they for mortar*[§]." The vessel of bull-rushes, in which Moses was exposed on the banks of the Nile; "*she took for him an ark of bull-rushes, and daubed it with slime and pitch*[*]."

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[*] Lib. xxiv. cap. 7.

[†] De Natura Fossil. lib. iv. p. 595.

[‡] Genesis, cap. vi. ver. 14.

[§] Genesis, cap. xi. ver. 3.

We have, perhaps, not sufficient authority, either from the words which the English translators of the Bible have here employed, or from the words adopted in the Hebrew, to rest on more than probability, that it was bitumen that was used in coating over the ark of Noah; or in covering the vessel of bull-rushes, in which Moses was exposed on the banks of the Nile. Little doubt, however, can exist, that it was the substance which the builders of the tower of Babel employed, instead of mortar. In proof of this, we learn, from some modern travellers, that the remains of buildings have been discovered, in which bitumen had been thus employed, instead of mortar; and that there existed every reason to believe, that this was on the very spot on which Babylon stood.

That this was really the site of the ancient city of Babel, appears to be very evident, from the information obtained by the learned researches of Major Rennell. Abulfeda, he says, an oriental geographer, states that the ancient city of Babel, has now nothing more than a village on its site; and that this village, Hellah, stands on the land of Babel. This account is very much corroborated by the Turkish geographer, Ibrahim Effendi, who says, that Babel is close to Hellah; and modern travellers agree, that the Arabs, and the inhabitants on the spot, give the name of Babel to the district round about Hillah; and point out vast ruins, as the remains of the ancient city, spoken of by Abulfeda.

The city of Babylon, in the opinion of Major Rennell, formed from a careful examination and comparison of the several accounts given by different authors, must have been at or near the present city of Hillah, or Hellah, which is known to have been built of the bricks of the ancient city; and, is even said to stand on a part of its very site. Herodotus adds, that the fountains of bitumen at Is, from whence the bitumen used in the construction of Babylon was brought, were situated at eight days journey above that city: and as, according to M. Niebuhr, there are copious fountains of bitumen near Hit, a town of the Euphrates, one hundred and twenty-eight German miles above Hillah, reckoning the distance along the bank of the Euphrates, the learned illustrator of Herodotus thinks there can be no doubt, therefore, that Hit is the place intended by Is, which should have been written *It*.

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[*] Exodus cap. ii. ver. 3.

Mr. Beauchamp, whose account is translated in the European Magazine for 1792, says—"The quantity of bitumen that must have been employed in building Babylon, is scarcely credible. Most probably," he says, "it was procured from Hit, on the Euphrates, where we still find it. The master mason told me, that he found some in a spot which he was digging, about twenty years ago, which is by no means strange, as it is common enough on the banks of the Euphrates. I have, myself, seen it on the road from Bagdad to Juba, an Arabian village, seated on that river."

Major Rennell[*] remarks, in corroboration of this statement, that Diodorus says[†], that great quantities of bitumen flow out of the ground at Babylon; that these springs supplied it for the building of the city; and that it was even used for fuel. Major Rennell is of opinion, that, perhaps, only such of the public buildings were cemented with bitumen, which were exposed to the weather, or to inundations. This agrees with a modern custom in these parts; for, on occasion of an inundation, about the year 1733, the walls, in Bagdad, were covered with a composition, of which bitumen made a part[‡]. The cement in the remarkable fortress of Alkadder, in the Chaldean desert, according to Mr. Carmichael's description of it, appears to be bitumen. The wall of Media, which shuts up the isthmus between the Euphrates and Tigris, above Babylon, was built of burnt bricks, laid in bitumen[*]; and the walls of Perisabour, in Babylonia, taken by Julian, were of the same materials[†]. So that in those days bitumen was much in use as a cement; but it appears to have been disused in succeeding times.

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[*] P. 369. [†] Lib. ii. cap. 1. [‡] Ives's Travels, p. 281.

According to Herodotus, a composition of heated bitumen was used in building, as a cement, in the place of mortar; being mixed with the tops of reeds, and placed between every thirtieth course of bricks[‡]. This account of Herodotus is confirmed by the reports of modern travellers; except that some have found the bitumen thus disposed, at every seventh or eighth course: and M. Beauchamp found it at every course, in some of the remaining buildings of Babylon.

From the accounts of various travellers, two different sorts of bricks appear to have been employed in the supposed buildings of the ancient city of Babel: the one kind seeming to have been baked, by fire, and the others, by the heat only of the sun. Some of these appear to have been deposited in lime and sand, or only in clay, and others in bitumen: osiers or reeds having been also used, perhaps, as hair is employed in the mortar of the present day, to augment the adhesiveness of the cementing matter.

Having been favoured with some fragments of the bricks, taken from some ruins near Hillah, accompanied by some of the bitumen, I was astonished to find that the bitumen, which, from its external appearance, might have been suspected of having lost all its combustibility, still inflamed, on being brought into contact with the flame of a candle, and yielded a very strong bituminous smell. Some of these bricks had, on one side, an unknown inscription;

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[*] Xenophon. An. lib. ii. [†] Amm. Marc. lib. 24. [‡] I. Clio. c. 178, & seq.

and on the other, the bitumen adhered; and, on those parts which were not covered by bitumen, on the other side, the marks of matting appeared, on which it was supposed they had been placed to dry.

From every concurrent testimony, we have, therefore, reason to conclude, that bitumen was the tenacious substance which the sacred historian meant to describe, as the substitute for mortar, employed by the builders of the town of Babel. Nor can it be observed, without considerable pleasure, that these discoveries serve strongly to evince the high degree of fidelity which pervades the Mosaic history.

Strabo, who also speaks of the ruins of Sodom, which, he says, were sixty furlongs in compass, and were then to be seen on the shores of the Dead Sea[*], relates, that the waters of the lake Sirbon are so heavy in their nature, that those who attempt to dive in them, are raised up as soon as they sink as low as the navel. It is full of bitumen, which rises from the bottom in bubbles, like those of boiling water, giving to the waved surface of the lake an appearance as if little hills were arising from it. The bitumen, he supposes to have been liquefied by heat, and then diffused and condensed in the water, on which it floats from the peculiar nature of the water: and is afterwards obtained by the neighbouring inhabitants, who for this purpose were rowed to it on rafts[†].

Causabon, Lancisius, in his Notes on Mercatus's Metallotheca, and others, are of opinion that Strabo has here, by some mistake, referred to lake Sirbon, that assemblage of curious circumstances which more properly belonged to the lake Asphaltin. Indeed his description, of which a sketch only is here given, corresponds very nearly, in every particular, with that given by Diodorus Siculus of the last mentioned lake.

[*] Strabonis Geogr. lib. xv.

[†] Ibid. lib. xvi.

Marcellinus Ammianus states, that the Persians were used to anoint their arrows with it; and, when thus lighted, to shoot them into the roofs of their enemies houses, to set them on fire.

Josephus[*] describes the lake Asphaltitis, or lake of Sodom; and particularly mentions no fish being able to live in it, the buoyancy of substances thrown on it, and of large lumps of bituminous matter floating on it, not unlike the bodies of bulls without heads. The length of this lake is five hundred and eighty furlongs, the breadth of it an hundred and fifty. It runs out from the river Jordan, as far as Zoar, in Africa, and borders upon the land of Sodom; where, he says, are yet to be seen the remains of five abominable cities, that perished in the conflagration produced by a judgment of fire from heaven.

In Samosata, a town of Syria, Pliny relates, there was a pool which yielded an inflammable substance, called *maltha*[†]. Of the same nature, he observes, is *naphtha*, which flows in the manner of a liquid bitumen, and is found in Austragena, in Parthia[‡]. He also informs us, that the lake Asphaltitis produces nothing but bitumen, whence its name. It will not receive into it the bodies of any animal; oxen and camels therefore float on it: and hence the report that nothing sinks in it[§].

Ælian, Dion Cassius, and other writers, have dwelt with admiration on the wonders of Nymphæum, on the confines of Appollonia; where, they say, there is a pit which is kept filled with bitumen, which rises from the earth in the same manner as a spring of water. Not far from thence is a place where continual flames are seen arising from the earth; notwithstanding which, the earth is not burnt, nor do the plants and trees, which grow there, wither from the effects of the fire; but flourish and grow to a considerable height.

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[*] Lestrange's Translation, Wars of the Jews, book v. cap. 5.

[†] Lib. ii. cap. 104. [‡] Lib. ii. cap. 105. [§] Lib. v. cap. 16.

Bitumen, in this fluid state, has been called by some Latin writers, *oleum vivum*. Thus

> Vulcano condicta domus, quam subter eunti
> Stagna sedent venis oleoque madentia vivo.—GRATIUS.

Hieronymus observes, that the lake Asphaltitis is called the Dead Sea, because no animal can live in it: and if any fish, by chance, come into it, they soon die, and swim on the surface*.

Diodorus†, who wrote about forty years before Christ, relates, that Demetrius, after his battle with Ptolomæus, formed his camp on the Asphaltine lake, which, he observes is highly worthy of description. He describes it as situated in the middle of the province of Idumæa, being five hundred stadia in length, and sixty in width. Its water was so bitter and fetid, that no fish, nor any other animal, could live in it: and, although many rivers of fresh water emptied themselves into it, its strong odour was still prevalent. On the middle of this lake, a mass of solid bitumen arose every year; sometimes more than three acres, and at other times rather less than one acre, in extent. The barbarous inhabitants of the borders of the lake, named the larger mass, The Bull, and the smaller, The Calf. As the bitumen swam upon the water, it appeared to those who viewed it from a distance, to resemble a kind of island. The rising of the bitumen, he says, is preceded for twenty days by certain peculiar signs. The smell of the bitumen, with an injurious vapour, is diffused to the distance of many stadia around the lake; and whatever articles of gold, silver, or brass, are within its influence, lose their original colour; which they however regain when all the bitumen has exhaled. A neighbouring spot, under which a subterraneous fire exists, yields a vapour which smells much more strongly, and which renders the inhabitants unhealthy and short lived; and to which, perhaps, this change of the surface of metals is more properly attributable. In a valley near to this spot, he observes, the substance called *balsam* is found, which is productive of a considerable income; since in no other part of the world, he remarks, is this substance to be found, the use of which, as a remedy, is so very considerable.

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* Hieronym. in Ezekiel, sec. xlvii.

† Diodori Siculi Bibliothecæ Historicæ, interprete Laurentio Rhodomano.

Those who inhabit the borders of the lake, adopt a mode, he says, by which, without the aid of ships, they obtain, and carry home, the bitumen which floats on the lake. Having tied together bundles of large reeds, so as to form rafts, three persons, two with oars, and one armed with a bow and arrows, to repel the inhabitants of the opposite shore, proceed to the floating bitumen. Having reached the object of their voyage, they get on to the bitumen, and load their rafts with pieces, resembling a soft stone, which they cut from it with hatchets, with which they are purposely provided. If, whilst thus employed, any one happens to fall into the lake, our author informs us, that, although not a proficient at swimming, he will not sink, as would be the case in other waters, but floats as well as the most expert swimmer. The bitumen being brought ashore, is afterwards carried to Egypt, and sold for the purpose of embalming the dead: for with this substance, mixed with various aromatics, they are able to preserve the bodies of the dead for a considerable time.

We learn, from Agricola*, that bitumen was collected, in various parts, in different degrees of thickness, and by different means, adapted to its consistence and quantity. That it is exceedingly inflammable, so that any body being anointed with it, and particularly with that species of it called naphtha, and having fire applied to it, would be thereby burnt; water not extinguishing it, unless applied in great quantity, the flame being best smothered by clay, earth, dust, or any such dry substances. From its so readily taking fire, it was used, in many places, instead of oil, for the supply of lamps. Thus it was employed in Sicily, being found in the plain of Agrigentum, whence it was called Sicilian oil. It was also found, he says, near Soli, in Cilicia; near Babylon; at Ecbatania, in Ethiopia; and in various parts of India. The common people of Saxony employed it, Agricola also tells us, not only in their lamps; but made with it nuptial torches, by dipping into it the dried stalks of torch-weed, or mullein. They also employed it to grease their carriage wheels; to defend different articles of iron and copper, from rust; and to protect wooden posts, from the injuries of the weather: and, for the same purpose statues were sometimes covered with it.

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* De Natura Fossilium, p. 324. edit. Basileæ, 1559.

Alexander, it is said, for the sake of experiment, set fire to the naphtha, with which he had ordered the body of a boy to be covered, by which the youth was extremely burnt; so that he must have perished, if the attendants had not, by pouring over him large quantities of water, overpowered the flame, and thereby saved him.

We are informed by Valerius Cordus*, that in the plains of Brunswick, bitumen is dug in a moderately hard state; and that there also bitumen, fluid as oil, runs into pits hollowed out for the purpose. The country people adopting it for the uses already mentioned. Bitumen, he observes, is also found in the Alps of Switzerland.

He also relates, that a hard black bitumen is found, most copiously, in a certain hill, in the way from Falkenburg to the village of Sattela. The best, however, is found about Sattela, and in the village itself.

Yours, &c.

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* Valerii Cordi Observationes quædam Rerum naturalium variarum, &c. MDLXI.

LETTER XIV.

ACCOUNT OF BITUMENS CONTINUED, FROM MORE MODERN AUTHORS....RAY, DOLOMIEU, &c....TAR LAKE IN THE ISLAND OF TRINIDAD....PETROLEUM WELLS IN THE BURMHA DOMINIONS ....RUSSIA, &c.

IN my last I shewed you the notice which these substances have obtained from writers of the highest antiquity: in this, I purpose to place before you such remarks of more modern writers, as appear to be most deserving of your attention.

According to the relation of Hasselquist, asphaltum is gathered by the Arabs, in considerable quantities, every autumn, on the shore of the Dead Sea. It is carried by them to Damietta, and there sold; being employed, he says, in dying wool *.

In the Island of Zante, in the Venetian dominions, there is a spot, which, on being trod upon, shakes under the feet like a quagmire; in the neighbourhood of this part are springs, which yield a considerable quantity of bitumen, and particularly, it has been remarked, to be affected during the time of earthquakes. It is much employed, instead of pitch, in paying the bottoms of ships: upwards of a hundred barrels in a year being used for this purpose.

At Gabian, about a day's journey from Montpellier, in the way to Beniers, is a fountain of petroleum. It burns like oil, is of a strong pungent scent, and a blackish colour. It distils out of se-

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* Hasselquist's Voyages and Travels in the Levant, p. 284.

veral places of the rock all the year long; but most in summer-time. They gather it up with ladles, and put it into a barrel, set on one end, which hath a spiggot just at the bottom: when they have put in a good quantity they open the spiggot, to let out the water; and when the oil begins to come, presently stop it. They pay for the farm of this fountain, about fifty crowns per annum [*].

The lake Palius, or Paliorum Lacus, in the valley of Noto, in Sicily, according to the account of M. Dolomieu, has sometimes petroleum on the surface of the water: and the mud at the bottom, and on the bank, which has a black colour, is tenacious, and smells like pitch. The whole soil of the small plain around it consists of black, tough, resinous, inflammable earth A few years ago, some straw huts in this neighbourhood having been set on fire, the fire was communicated to the ground, which burnt with a whitish dull flame, like that of the inflammable springs in Dauphiny, during several months, and was extinguished with the greatest difficulty; as the fire, when extinguished in one place, broke out in another [†].

Olearius mentions its being found in Persia [‡]. It is also found in Norway, in Scotland, in Aquitania, and in Alsace.

The *Mumiahi*, or *Mumia nativa Persiana*, as described by Kempfer, in his *Amœnitates Persi*, proceeds from a rock. The native place of the best mummy is far from the access of men, from habitations, and from springs of water, in the province of Daraab. It is found in a narrow cave, not above two fathoms deep, cut like a well, out of the mass, and at the foot of the rugged mountain Caucasus.

On the south side of a mountain, the northern declivity of which terminates in the valley of Travers, between Travers and Couvet, near to Neuenberg, there are two large pits, containing asphaltum;

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[*] Ray's Travels, p. 256.

[†] Magazin sur das neueste aus der Physik, vol. iii.

[‡] Olear. Itin. Pers. lib. vi. c. 9.

which, in the year 1758, had been worked upwards of forty years; their produce being sent to different parts of the continent. On digging at the same height, on the other side of the hill, the same substance was found *.

Mr. Anderson describes, in the Philosophical Transactions, a remarkable lake, or rather plain, of bitumen, in the island of Trinidad, known by the name of the TAR LAKE; and by the French called *La Bray*, from its resemblance to pitch, and its answering the intention of ship-pitching. It lies on the leeward side of the island, about half way from the Bocas, to the south end, where the mangrove swamps are interrupted by the sand banks and hills; on a point of land which extends into the sea about two miles, exactly opposite to the high mountains of Paria.

This cape, or headland, is about fifty feet above the middle of the sea, and has the greatest elevation of land on that side of the island. From the sea, it appears a mass of black vitrified rocks; but, on a close examination, it is found to be a composition of bituminous scoriæ, vitrified sand, and earth, cemented together. In some parts, beds of cinders only are found. In approaching this cape there is a strong sulphureous smell; which is prevalent in many parts of the ground, to the distance of eight or ten miles from it.

This point of land is about two miles broad; and, on the east and west sides, for the distance of about half a mile from the sea, falls with a gentle declivity to it; and is joined to the main land, on the south, by the continuation of the mangrove swamps; so that the bituminous plain is on the highest part of it, and only separated from the sea, by a margin of wood which surrounds it, and which prevents a distinct prospect of it. Its situation is similar to a savannah, and, in like manner, is not seen until treading on its verge. Its colour, and even the surface, presents, at first, the aspect of a lake of water. But Mr. Anderson imagines it obtained the appellation of lake, when seen in the hot and dry weather: at which time its surface, to the depth of an inch, is liquid; and then, from its cohesive quality, it cannot be walked on.

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* C. Ludov. l'Agascherie du Blé, Dissertatio Medica sistens Examen Bituminis Neucomensis, p. 11. 1758.

It is of a circular form, and above three miles in circumference, appearing at first a plain as smooth as glass; excepting some small clumps of shrubs and dwarf trees, that have taken possession of some spots of it: but, on a nearer view, it is discovered to be divided into *areolæ* of different sizes and shapes; the chasms or divisions anastamosing, through every part of it. The surfaces of the *areolæ* are perfectly horizontal and smooth; the margins are undulated, and each undulation is enlarged to the bottom, till it joins the opposite. On the surface, the margin, or first undulation, is distinct from the opposite, from four to six feet; and the same depth before they coalesce: but where the angles of the *areolæ* oppose, the chasms or ramifications are wider and deeper. When Mr. Anderson was there, these chasms were full of water: the whole forming one true horizontal plain, which rendered his investigation of it difficult and tedious; being necessitated to plunge into the water a great depth, in passing from one *areolæ* to another. The truest idea that can be formed of its surface, would be from the *areolæ*, and their ramifications, on the back of a turtle. Its more common consistence and appearance, is that of pit-coal; but its colour is rather greyer. It breaks into small fragments, of a similar appearance, and glossy; with a number of minute and shining particles interspersed through its substance. It is very friable; and when liquid, is of a jet black: some parts of the surface are covered with a thin brittle scoriæ, a little elevated. As to its depth, he could form no idea of it, for in no part could he find a substratum of any other substance. Its smell resembled that of pitch, and it was so hard, that no impression could be made on its surface, without an axe. At the depth of a foot it was found a little softer, with an oily appearance, in small cells. A little of it held to a burning candle made a hissing or crackling noise like nitre, emitting small sparks, with a vivid flame, which extinguished the moment the candle was removed. A piece, put into the fire, boiled up a long time, without suffering much diminution. After a considerable exposure to severe heat, the surface burned, and formed a thin scoria, under which the rest remained liquid. A gentle heat renders it ductile; hence when mixed with a little grease, or common pitch, it is much used for the bottom of ships; for which intention it is collected by many.

Besides this place, where it is found in this solid state, it is found liquid, in many parts of the woods; and at the distance of about twenty miles from this, it is found about two inches thick, in round holes of three or four inches diameter, and often at cracks or rents. This is constantly liquid, and smells stronger than when indurated; and adheres strongly to any thing it touches: grease being the only thing that will divest the hands of it. The soil, in general, for some distance round La Bray, is cinders and burnt earth, and where not so, is a strong argillaceous soil; the whole being exceedingly fertile. For thirty miles round, there is the appearance of the convulsions of nature, from subterraneous fires; and, in several parts of the woods, hot springs are discovered.

The Abbé Fortis, in his Travels in Dalmatia, describes what he terms a mine of pissasphaltum, which he saw in the Isle of Bua. By this mine he means marble strata, more than twenty-five feet perpendicular, which sustain the irregular masses that surround the top of the mountain. From some of these strata tears of pissasphaltum ooze out most abundantly, when the sun falls on the marble rock in the heat of the day. This pissasphaltum he describes as of the most perfect quality; black and shining, like the *bitumen judaicum;* very pure, odorous, and cohesive. It comes out almost liquid, but hardens in large drops when the sun sets. On breaking many of these drops on the spot, almost every one of them was found to have an inner cavity full of very clear water. Who can tell, the Abbé exclaims, whence it came there, or what very remote combustion of woods, or what volcano produced it*? In the valley of Coccorich, in the *Primorèe*, in Dalmatia, is also a mine of pissasphaltum, resembling, in most respects, that of the Isle of Bua †.

From the very interesting account of the petroleum wells in the Burmha dominions, related by Captain Hiram Cox, in the Asiatic Researches, it appears that the strata of the place in which they are found, are first a light sandy loam intermixed with fragments of quartz, flint, &c.—2dly, A friable sand-stone, easily wrought, with thin horizontal strata of a concrete of martial ore, talc, and indurated clay.—3dly, At seventy cubits, more and less, from the surface and immediately below the free stone, a pale blue argillaceous earth (schistus) impregnated with the petroleum, and smelling strongly of it. This is very difficult to work, and grows harder as they get deeper, ending in schist or slate, such as is found covering veins of coal in Europe, &c. Below this schist, at the depth of about an hundred and thirty cubits, is coal. Captain Cox procured some, intermixed with sulphur and pyrites, which had been taken from a well, deepened a few days before, but deemed amongst them a rarity, the oil in general flowing at a smaller depth. They were piercing a new well when the Captain was there, and had got to the depth of eighty cubits, and expected oil at ten or twenty cubits more. When a well grows dry they deepen it. They say none are abandoned for barrenness.

The oil is drawn pure from the wells, in the liquid state, as used, without variation; but, in the cold season, it congeals in the open air; and always loses something of its fluidity: the temperature of the wells preserving it in a liquid state fit to be drawn. The oil is of a dingey green, and odorous; it is used for lamps, and boiled with a little *dammer* (a resin of the country); it is employed for paying the timbers of houses, the bottoms of boats, &c. which it preserves from decay and vermin. It is said, that no water ever percolates through the earth into the wells, that which penetrates into the earth is effectually prevented from descending to any great depth by the oleaginous clay and schist: this will be readily admitted, when it is known that the coal mines at Whitby are worked below the harbour, the roof of the galleries being not more than fifty feet from the bed of the sea.

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* Travels in Dalmatia, by Abbé Alberto Fortis, p. 176.

† P. 304.

From a careful enquiry, the Captain makes the average produce of each well, per annum, to be seven hundred and ninety-three hogsheads, of sixty-three gallons each; and, as there are five hundred and twenty wells registered by government, the gross amount of the produce of the whole, per annum, is 92,781 tons 1,560lbs. or 412,360 hogsheads.

Captain Cox observes, this oil is a genuine petroleum, possessing all the properties of coal tar; being, he thinks, the self same thing; the only difference is, that nature elaborates in the bowels of the earth that for the Burmhas, for which European nations are obliged to the ingenuity of Lord Dundonald*.

From the observations of Professor Pallas, as well as from the accounts of Mr. Tooke, it appears that fluid bitumen is found in various parts of the Russian empire. Naphtha sources are discovered on the stream Igar, fifteen versts from Sergiefsk, on the Samara, and others forty versts from it. They yield considerable quantities of naphtha. On the Terek, in the mountains about the warm springs at Baragun, near Deulet, Gueray, &c. naphtha and petroleum are often found; and the sources of Ischelschengisk, are particularly pro-

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* Asiatic Researches, vol. vi.

Francisci Ariosti de Oleo Montis Zibinii, seu Petroleo Agri Mutinensis. These springs have also been noticed by Frassoni, in 1660, in a pamphlet intitled *Thermæ Montis Gibii;* by Ramazzini, in 1698; and by Vallisneri, in 1711.

Bituminous substances in various degrees of solidity and purity are found in several parts of England; as is indeed the case in most parts in the neighbourhood of which coals are found to exist.

Dr. Plot, in a discourse concerning perpetual sepulchral lamps, read before the Dublin Society, 1684[*], mentions that at Pitchford, in Shropshire, there is a naphtha or liquid bitumen, that constantly issues forth with a spring there, and floats upon the water. This, the Doctor thinks, might be separated, before it joins the water, into a channel of its own; and so conveyed to a place thought most convenient for such a lamp, into which it should perpetually distil, as it does now into the fountain. For, the Doctor observes, a brush or wick of asbestos, or of gold wire, might be employed, and if the oil be properly disposed, then, says the Doctor, we have an oil as everlasting as our wick: nor need we fear any extinction, if inclosed in a tomb or vault under ground, in never so damp and moist a place; it being, he adds, the characteristic of bitumen, to burn best where there is moisture, as is evident upon affusion of water upon sea coal.

Among the inflammable minerals of Derbyshire, Mr. Mawe, whose opportunities of observation are as great, as his collection is interesting, observes[†], the most remarkable is the elastic bitumen, in its various states. It is generally, he says, found between the stratum of schistus and lime-stone; rarely in small cavities, adhering to the *gangart*, and sometimes containing lead ore, fluor, &c. When first detached, its taste is very styptic, as if blended with decomposed pyrites. It varies in colour, from the blackish or greenish brown to the light red brown, and is easily compressed; but sometimes the same piece is less elastic in one part than another. On burning it, the smell is rather pleasant.

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[*] Mr. Ayscough's Catal. 4311. Plut. vi. E. vol. i. 34, 1684.

[†] The Mineralogy of Derbyshire, by John Mawe, p. 92.

The varieties of this fossil, described by Mr. Mawes, are—1. Elastic bitumen, of a reddish brown colour, containing nodules of indurated shining black bitumen, resembling jet.—2. A piece in a marine shell, in lime-stone.—3. Dull, red and transparent, in crystallized fluor.—4. Composed of filaments, like soft cawk, and of a singular acid taste.—5. Indurated amorphous masses and globules of a shining black, like jet; sometimes liver-coloured; electric, when rubbed.—6. With asphaltum, and containing lead ore; and the same in long filaments, almost as fine as wire.

A considerable spring of petroleum exists at Colebrook Dale. This spring was discovered at about thirty yards in depth, whilst digging to form an arch-way to convey the coals from a very deep pit. It was at first found to ooze from between the crannies of the rock, but soon began to pour out in a considerable stream, running even into the Severn. Large iron pipes are employed for the conveyance of the fluid into proportionably sized pits, which have been sunk for its reception. Hence it is conveyed into immense caldrons, in which it is inspissated, by boiling, to the consistence of pitch. Whilst fluid, the tar, which appears to be remarkably free from impurity, has rather an agreeable odour; and when inspissated, it exactly resembles the asphaltum of the Dead Sea. Since its first discovery, three different springs of it have broken out, one of which pours out a considerable quantity. Near to the celebrated iron bridge, this bituminous fluid is emitted pretty copiously, being almost pellucid, but thicker than treacle. A similar rock with that from which the petroleum flows may be traced upwards of seven miles: the coals, which are found at some depth beneath the petroleum, are of an exceeding good quality.

From the experiments of Mons. Boulduc*, made on naphtha, we learn, that it is so inflammable, that it takes flame before the flame which is brought towards it is really in contact with it; that, when heated in a vessel, it inflames by the flame of a candle held at a considerable distance above it, a subtile vapour extending some feet above the fluid; and that it will burn freely on the surface of water. He also states, that it is so light as to swim on the surface of all fluids, even on that of rectified spirits of wine, which is heavier than it by one-seventh, and does not manifest any action on it. One drop diffused itself over water to more than the space of a toise, the water yielding prismatic colours. It mixed perfectly with the essential oils, particularly with the oils of turpentine, of thyme, and of lavender. He observed also, that it did not inflame on the addition of the concentrated acids, but became thickened on their union with them. A piece of paper soaked with it, soon became dry, and then, as is the case when spirit of turpentine is used, ceased to be transparent.

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* Histoire l'Academ. Royale des Sciences, 1715, p. 15.

By distillation with a gentle heat, du Blé*, obtained from the asphaltum of Neuenberg, a light and limpid oil, which, like naphtha, was so subtile, as to evaporate very rapidly in the open air; spreading very freely on the surface of water, and taking flame very readily. But unlike naphtha, which, according to Boulduc, will not unite with alcohol, this essential oil entered into union with alcohol with the same facility as oils of lavender and turpentine.

By properly adapted experiments, he also ascertained, that in the asphaltum of Neuenberg, both the sulphuric and muriatic acids existed, in union with calcareous earth.

Fourcroy states, that there is obtained, from brown petroleum, by distillation, an acid phlegm; and an oil which at first resembles naphtha, but which becomes coloured as the distillation proceeds.

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* C. Ludov. l'Agascherie du Blé, *Examen Bituminis Neocomensis*, 1758.

There remains in the retort, a thick matter like maltha, and which may, by farther exsiccation, be rendered dry and brittle, like asphaltum; and by a greater or longer continued heat, may be reduced to a charcoal.

The alkalies have but little action on petroleum. The sulphuric acid darkens, thickens, and inflames it; the same as it does the volatile oils. Petroleum readily dissolves sulphur: it becomes coloured by the metallic oxides, and unites with amber, which it softens, and, in part, dissolves, by the aid of heat.

Fourcroy obtained from asphaltum, by distillation, an acid phlegm and a coloured oil, like petroleum. By fusion, he found asphaltum united intimately with sulphur, phosphorus, the fixed and volatile oils, resins, gum-resins, and many of the metallic oxides. Alcohol appeared not to touch it all; ether had an evident, but a feeble action upon it.[*]

Yours, &c.

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[*] Systeme des Connoissances Chymiques, tom. viii. p. 238.

who frequently mentions it, relates, that the lake Cephisis, near to the Atlantic sea, and which the Moors call Electrum, yielded, when heated by the sun, amber, which flowed from its mud.

It is generally found either within the earth, floating on the waters, or on the sea shores. In Poland, Prussia, Silesia, Pomerania, Bohemia, and many other places in that tract of Europe, it is frequently found, when digging to the depth of a few yards. Hermann relates, that he found amber in an island near the Cape of Good Hope. It is also found in various parts of Germany, both underground and on the shores, where it has been thrown by the waves of the sea: but it is found in the greatest plenty on those shores which are washed by the waves of the Baltic. It is frequently found on the sea shores of several parts of England, most probably brought by the waves, which have already washed the shores of those countries, in which this substance so plentifully abounds. It has also been dug up in detached pieces in several parts of England. The pits dug for tile-clay, between Tyburn and Kensington, and that pit which was opened behind St. George's hospital, at Hyde Park Corner, have been said, by Sir John Hill, to have furnished some very fine specimens.

In the cabinet of the Grand Duke of Tuscany, it is said, there is a column of amber of a beautiful colour and brilliant lustre, ten feet in height. This, however, is strongly suspected to be only an artificial imitation of this substance. In the museum of his Majesty the King of Prussia, is a burning lens made of clear amber, a foot in diameter. From its yielding to the tools of the artist, amber is often formed into trinkets of a very pleasing appearance.

The extraneous or adventitious bodies, which are sometimes found in amber, considerably enhance, by their curiosity, the value of the specimens in which they are found. In some specimens drops of water, and in others fragments of gold and silver, have been said to have been inclosed; but examination will generally demonstrate, that what has been so supposed are pieces of splendid pyrites. Flies, small phalæna, and ants, or parts of these insects, are the foreign matters which are most commonly thus entombed. From the perfect state of preservation in which these are found, displaying the sound appearance and fresh colouring of life, these specimens excite the highest degree of interest. The position in which these insects are found, frequently with their limbs separated, as though by struggling to obtain their release, proves that they have been thus engaged and inviscated, by alighting on this substance whilst it was in a soft state. In the Metallotheca Vaticanæ of Mercatus, edited and brought into public notice by the splendid illustrations of Lancisius, are excellent representations of various insects thus preserved, as well as of some other animals, such as small fishes, lizards, and frogs, in a similar state of preservation. These latter have, however, been suspected of being thus involved by some artificial process, especially as the high price which such rare specimens would obtain would be a sufficient inducement to such ingenious exertions. In the splendid and elegant work of Sendelius* are displayed a prodigious number of figures of specimens of amber, containing animalculæ, insects, &c.

Animals thus naturally embalmed have furnished the poet, as might be expected, with an interesting topic. Martial thus elegantly speaks of a viper inclosed in amber:

> Flentibus Heliadum ramis dum VIPERA serpit,
> Fluxit in obstantem succina gumma feram;
> Quæ, dum miratur, pingui se rore teneri,
> Concretó riguit vincta repente gelu.
> Ne tibi regali placeas, Cleopatra, sepulcro,
> Vipera si tumulo nobiliore jacet. *Lib. IV. Epigr.* 59.

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* Historia Succinorum, Corpora aliena involventium ex regiis Augustorum Cimeliis Dresdæ conditis. Lips. 1742.

With equal elegance he notices the ant and the bee, entombed with similar splendor:

Dum Pheathontea FORMICA vagatur in umbra,
  Implicuit tenuem succina gutta feram.
Sic, modo quæ fuerat vita contempta manente,
  Funeribus facta est nunc pretiosa suis. *Lib.* [illegible] *Epigr.* 15.

Et latet, et lucet Pheathontide condita gutta
  Ut videatur APIS nectare clausa suo.
Dignum tantorum pretium tulit illa laborum:
  Credibile est ipsam sic voluisse mori. *Lib. IV. Epigr.* 32.

The celebrated Breynius transmitted, about the year 1665, to the Royal Society of London, an account of a curious piece of amber which had fallen under his observation *. This specimen was shewn to him by an Englishman, a Dantzic merchant, of the name of Benlows, who valued it at thirty guineas. It was of an oval compressed figure, about two inches and a quarter long, about half that measure in width, and a quarter of an inch in thickness; of that colour, described by Pliny, resembling Falernian wine; and exceedingly fair and clear, not having the least mark from which any suspicion of fraud could arise. It contained through its whole length an extended leaf of the pinnated kind, yielding a beautiful object, shining with a golden splendour, from the various refractions and reflections which the rays of light suffered from the surrounding medium. The leaf was not perfect, but mutilated at each extremity, and was formed by five pair of oblong and somewhat sharp-pointed pinnæ, placed at nearly equal distances, and being in some places evidently eaten. What plant it belonged to he was however unable to determine, since many different species of this family are clothed with leaves so nearly resembling each other, as not to allow the difference in a single frond to be discovered; especially when, as in this instance, the surrounding amber prevented a perfect examination: so that, even with the aid of a magnifying glass, the veins of the leaf could not be seen. The plant, however, to which it appears to approach the nearest, is, he thinks, the *securidaca secunda*, of *Clusius*, or the *coronilla herbacea*, of Tournefort, which is very common in the fields of Prussia. On the one side of the frond was a small fly, and on the other a spider; but neither of them were perceptible without the help of a glass.

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* Observatio de Succinea Gleba, Plantæ cujusdam Folio impraegnata rarissima. Auctore D^{no} Johanne Philippo Breynio, M.D. F.R.S.

In the Metallotheca of Mercatus is also the representation of what appears to be a small leaf of the *coronilla herbacea, flore vario*, of Tournefort, or of the *onobrychis secunda, Clusii*, which is also very frequently found in the Prussian fields.

Agricola had observed, two or three hundred years ago, that by the distillation of amber it was resolved partly into an oil, bearing a similar colour with amber, and partly into a dark bitumen, which, he remarks, so much resembles the bitumen of Judæa, as difficultly to be distinguished from it.

Mons. Bourdelin* relates some experiments which he made with this substance; amongst which the most worthy of notice is, that from two pounds of amber he obtained only eighteen grains of earth. He discovered the presence of an acid, which he imagined to be the muriatic.

It is now known that amber yields by distillation first an insipid phlegm, then a weak acid, which in the opinion of Scheele is the acetous acid, after this a volatile salt arises, and attaches itself to the sides of the receiver and the neck of the retort. This salt was first discovered to be of an acid nature by the Hon. Mr. Boyle;

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* Mem. de l'Acad. des Sciences, 1743.

and it has since been ascertained to be a peculiar acid, differing in some of its chymical properties, and in its affinities, from other acids. If the distillation be continued, the fire being augmented after the succinic acid is come over, a thick brown oil, which yields an acid taste, will be then distilled. But if water be employed in the distillation, a clear light oil will come over, which darkens by keeping, first becoming of a yellow, and then, by degrees, even of a dark brown colour.

JET is a compact, opaque, and very black substance, of almost a stony hardness; capable of receiving a high polish, and breaking with a conchoidal fracture, and a glassy lustre. Its specific gravity is 1.259. On being rubbed it manifests electric attraction; when heated it yields an odour resembling that of asphaltum, but not so powerful; and when inflamed, by a strong heat, it burns away, leaving an earthy residuum. It yields by distillation a bituminous oil, and an acid, which seems to resemble that of amber.

The term *succinum nigrum*, or black amber, has been applied by several ancient writers to this substance; and indeed with much propriety, it seeming to be the bituminous substance next in purity to amber, and approaching the nearest to it in its several properties. It may be considered as possessing the intermediate place between the purer bituminous matters and coals, it holding a sufficient quantity of charcoal to give it blackness; but has not suffered that kind of change which serves to correct the disagreeable odour which the less altered bitumens yield on the application of heat.

Although the surface of jet sometimes bears a striated and ligneous appearance, its conchoidal fracture evinces that closeness of structure which does not determine its separation, in any one particular direction more than another. Hence it is employed to form various trinkets, such as beads, buttons, &c. it yielding pretty readily to a careful application of the instruments of the turner.

This substance is thus spoken of by Marbodeus[*]:

> Nascitur in Lycia lapis, et prope gemma gagates,
> Sed genus eximium fœcunda Britannia mittit.
> Lucidus et niger est, et levissimus idem,
> Vicinas paleas trahit attritu calefactus,
> Ardet aqua lotus, restinguitur unctus olivo.

It is frequently found, as was known to Solinus, in various parts of this kingdom. It is very abundant in the neighbourhood of Liege, and particularly so in a celebrated mountain of coal, in Misena, not far from the city of Zuicca. It is also found in various parts of Spain, France, and Germany, and indeed in almost every part of the known world.

It is most frequently found in the neighbourhood of coal mines, on the sea shores, and in detached pieces in various subterranean situations; frequently in strata which are evidently alluvial. I have found it in the blue tile clay, beneath the gravel, at the depth of twenty feet, in the gravel-pits near Hackney; in pieces about one or two inches square, having pyrites adhering to them, and bearing on one side of them the striated structure of wood.

Cannel coal seems to be the bituminous substance next in purity to jet. It is a black, opaque, compact, and brittle substance: it breaks with a conchoidal fracture. Its specific gravity varies from 1.232 to 1.426. It does not soil the fingers. It kindles very easily, and burns with a bright white flame, like that of a candle, leaving an earthy residuum, and not caking into a cinder.

By the analysis of Mr. Kirwan, its composition is 75.20 of charcoal, 21.68 of bitumen, and 3.10 of aluminous and siliceous earths.

Like jet it possesses that compactness of structure which renders it susceptible of polish, and capable of being wrought into trinkets of various forms. The chief differences between jet and Cannel coal appear to be, that jet is found in detached masses, whilst Cannel coal is deposited in strata; and that jet, once set on fire, continues to flame for a considerable time, a bituminous vapour being at the same time exhaled; whilst Cannel coal requires to be so disposed, that its combustion may be aided by that of the surrounding fire, and by an increased rapidity of the accession of air. The difference of the chemical phenomena yielded by this substance and by jet appears to depend chiefly on the greater quantity of earth which enters, as a constituent part, into the composition of Cannel coal than into that of jet. The *terra ampelitis* of the ancients has been supposed by many to have been the substance we are here treating of; but the term seems, most generally, to have been applied to that species of loose bituminous earth which exists in those parts, in which fluid bitumens have prevailed.

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[*] *Dactylotheca Marbodei Galli: cum Scholiis Georgii Pictoris.* Basileæ, 1531.

The coal possessing these properties, and which is obtained from Lancashire, is that to which the term Cannel coal is most commonly applied; Cannel coal being the provincial expression for *Candle coal;* candle in the Lancashire dialect being pronounced cannel: the high degree of inflammability possessed by this substance having obtained for it this distinction. The coal called *Scotch coal*, from its being obtained from Scotland, possesses similar properties. It is obtained in large solid compact masses, and contains nearly as large a proportion of bitumen; it flames almost as freely as the former, and burns away to a white ash.

The Cannel coal of Wigan in Lancashire, the most beautiful coal of this species, is found, according to Mr. Godefroy de Villetaneuse, at the depth of seventy-six yards from the surface of the rock; over which is a stratum of earth, from three to eight yards in thickness. The first stratum of the rock, he states, to be two feet in thickness; laying on a metallic stone of a deep blue colour, forty-six yards thick. Underneath this is a vein of common coal, five feet in thickness; and thirty yards beneath this is found the Cannel coal, the thickness of which is one yard two inches.

Pits of similar coal have also been dug in Cheshire, and in some other parts of the kingdom.

Dr. Plot relates*, that the Cannel coal from Wednesbury common pit is of so close a texture, that it will take a passable polish; as may be seen in the choir of the cathedral church of Litchfield, which in great part is paved in lozenges, black and white, as other churches with marble; with Cannel coal for the black, and alabaster for the white. He also says, that at Beaudesart will work so very fine, that the king's majesty's head is said to have been cut in it, by a carver at Litchfield, resembling him very well.

Yours, &c.

LETTER XVI.

COAL DESCRIBED....DIFFERENT KINDS OF COAL....DOUBTFUL IF KNOWN TO THE GREEKS, OR EARLY ROMANS....BROUGHT INTO COMMON USE, IN THIS ISLAND, BUT IN MODERN TIMES.... FOUND IN VARIOUS PARTS OF THE WORLD.

I WAS much entertained by reading the account of your subterranean incursion; and have frequently since smiled at the ludicrous appearance you, and our friend Wilton, must have made, dressed in a collier's garb, and descending, by a bucket, down the shaft of a coal pit. The astonishment with which you were stricken, on your entrance into the pit, is forcibly expressed, by your saying, that it seemed as if you had discovered another world, just beneath the crust of that which you had lately quitted. There can undoubtedly be hardly any scene, which can be presented to the view, capable of exciting more astonishment than the one you describe.

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* The Natural History of Staffordshire, by Dr. Plot, p. 125.

Wonderful indeed must have been the scene, after a dark and dreary descent through so many fathoms of dripping strata, which must have offered itself, when you made your entrance into a cavern from which the glimpse of day was excluded; where the roof, the floor, and the walls, presented every where to the eye the same jetty black; except where the oozing drop, or the brilliant spar or marcasite, reflected the flames of the lamps; which, disposed in various parts, lighted the inhabitants of these seeming Vulcanian regions to their labours. These, as you inform me, were separating, with their ponderous instruments, into fragments of a convenient size, parts of the immense mass of coal, which years and years of labour had seemed to have left inexhaustible. Such an assemblage of striking and entirely novel appearances could not fail of exciting a train of thoughts widely different from any your mind had yet known, and must necessarily have rendered you anxious to gain some information as to the history of these regions. This part, as well as the rest, of my engagement, I shall perform with the utmost readiness, pleased with the idea that I may thus render your delightful tour more interesting and instructive.

Common coal, that substance so eminent for its utility to man as an article of fuel, is the fossil which therefore shall next claim our attention.

Coal is a black, solid, and compact substance, generally of a foliated or rather laminated structure, which necessarily directs its fracture. Its specific gravity is 1.25 to 1.37. It possesses a moderate degree of hardness, but is more brittle than Cannel coal; than which it also takes fire less readily, and is longer in consuming. It cakes into cinders more or less during its combustion, according to its degree of purity and the nature of the earths which enter into its composition. It has obtained various names, derived from certain varieties of its appearance, nature, &c. Thus, from its pitch-like colour and fracture, it has been sometimes called *pitch coal*; from the great degree of hardness which it sometimes possesses, *stone coal;* from its being obtained from a mine or pit, *pit coal*; and in London, for no better reason than its having been brought hither by sea, *sea coal.*

There are certain varieties of pit coal, which obtain their particular denominations from their mode of burning, or from their most obvious and predominant combinations. Hence we have *blind* or *deaf* coal; such is the Welsh and Kilkenny coal, kindling slowly and burning without flame or smoke to a stony flag. *Open-burning* coal, which does not cake, but burns with much flame and smoke, and is soon reduced to ashes. *Close-burning* coal, which kindles quickly, and melts and runs together like bitumen. Some coal is termed *slaty coal*, from its texture; and when it also contains a larger proportion of bitumen it is called *slaty Cannel coal. Culm* is a coal in small rough fragments, which does not melt or cake, but leaves behind it a slag of the same bulk with the coal employed, which yields a large portion of ashes, formed by argillaceous earth impregnated with iron.

If the translation of Sir John Hill[*] be admitted, and his arguments in support of it undoubtedly appear to be forcible, fossil coal was known in the time of Theophrastus. The passage is, "Those fossil substances that are called coals (ανθϱαϰας), and are broken for use, are earthy; they kindle, however, and burn like wood coals (ανθϱαϰες). These are found in Liguria, where there is also amber, and in Elis, in the way to Olympias over the mountains. These are used by the smiths."

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[*] Theophrastus's History of Stones, translated by Sir John Hill, p. 63.

He contends, that the meaning of Theophrastus is evidently, that *they kindle and burn like wood coals*, or, as we call it, charcoal; that being, he remarks, the genuine and determinate sense of the word ανθραξ in the other works of this author, in those of Pliny, and of all the other old naturalists. Even the more correct of the moderns, when they would express what we call pit coal, the substance which he contends is here described by this author, never use the words ανθραξ or *carbo* alone, but always carbo-fossilis, and λιθανθραξ.

Another passage of the same author seems also evidently to apply to coals: he relates that some of the more brittle stones become as it were burning coals, when put into fire, and continue so a long time. Of this kind are those about *Bena*, a town in Thracia; found in mines, and washed down by the torrents; for they will take fire on throwing burning coals on them, and continue burning so long as any one blows on them; afterwards they will deaden, and may after that be made to burn again: they are therefore of long continuance, but their smell is troublesome and disagreeable*.

Unless it be admitted that coals were known to Theophrastus, according to the opinion of Sir John Hill, we may, I believe, assert, that we have no proof of their having been known to the Greeks, or to the early Romans. The Latin does not even possess a name for this substance. Nor indeed is it to be wondered at that they should be thus ignorant of it, if, as is observed by the learned writers of the Encyclopædia Britannica, there are, in fact, no beds of it in the compass of Italy: the great line of that fuel seeming to sweep away round the globe, from north-east to south-west; not ranging at a distance even from the south-easterly parts of our island, as is generally imagined, but actually visiting Brabant and France, and yet avoiding Italy. It has been inferred from the circumstance of Cæsar's not having spoken of this substance, whilst describing this island and its productions, that coal had not then been discovered by the Britons. But, according to Whitaker, pieces of coal, with a quantity of slack, were dug up under the Roman way to Ribchester; and the same writer observes, that in the west riding of Yorkshire, and particularly in the neighbourhood of North Brierley, several large heaps of cinders have been found, which he supposes to have been deposited there by the Romans: a conjecture rendered probable by a number of Roman coins having been found in one of these mounds. Horseley, in his *Britannia Romana*, remarks, that there was a colliery not far from Brierley, which, in the judgment of those who are best capable of determining on such a point, appears to have been wrought by the Romans. Wallis, in his History of Northumberland*, to whom we are indebted for collecting these remarks, says, that the Romans were as well acquainted with our pit coal, as with our ores and metals. In digging up some of the foundations of the Roman walled city *Magna*, or Caervorran, in 1762, coal cinders, and some very large, were turned up. Mr. Pennant also observes, that a flint axe, used by the aborigines of our island, was discovered stuck in certain veins of coal exposed to the day in Craig y Pare, Monmouthshire; and in such a situation as to render it very accessible to the unexperienced natives, who in early times were incapable of pursuing the veins to any great depth.

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* Theophrastus on Stones, p. 53.

Excuse me, if I have been rather tedious, in thus producing authorities in proof of this commodity having been known and used by the primæval Britons. Remember that I am treating of that, which, from the great abundance in which it exists in this island, and from its superior quality, adds in a direct manner to the number of our comforts; and also gives indirectly to the country many peculiar and important advantages. This substance was not brought into common use, in this part of the British empire, until the reign of Charles the First; and even in Scotland, almost proverbially poor in vegetable, and rich in fossil fuel, it was at a very late period that coal was commonly used; for about the middle of the fifteenth century, when Æneas Sylvius* visited this island, he saw in Scotland poor people, in rags, begging at the churches, and receiving for alms pieces of stone, with which they went away contented. This species of stone, he says, whether impregnated with sulphur, or whatever other inflammable substance it may be, they burn in place of wood, of which their country is destitute.

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* Vol. i. p. 119.

Mr. Arnot says†, "Coal certainly was not discovered in the middle of the twelfth century, and it was as certainly known in the beginning of the thirteenth century. In the Leges Burgorum‡, which were enacted about A.D. 1146, a particular privilege is granted to those who bring fuel into boroughs. Wood, turf, and peat, are particularly mentioned, but with respect to coal there is a dead silence. But in the year 1234, Henry III. of England renewed a charter which his father had given to the inhabitants of Newcastle; and in this renovated charter he grants, upon their supplication, to the persons in whose favour the charter was conceived, licence to dig coal upon payment of £.100 a year, which is the earliest mention of coal in the island." And Boetius||, in his Description of Scotland, his native country, written in the beginning of the sixteenth century, says, "There are black stones also digged out of the ground, which are very good for firing; and such is their intolerable heat, that they resolve and melt iron, and therefore are very profitable for smiths and such artificers as deal with other metals."

In most countries of Europe has this valuable substance been found. Coal has been dug in France, Germany, and Sweden; and

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[*] Æneas Sylvii Opera, p. 443.

[†] History of Edinburgh.

[‡] Leg. Burg. c. 38.

[||] Boetii Scotorum Regni Descriptio, p. 10.

especially at Liege there are very considerable coal mines: but the mines of this island exceed, both in quality and extent, any that have yet been discovered. In Wales, coal is found almost through the whole principality. Ireland is also very far from being deficient in coal mines; although they have not yet been found in such abundance as in other parts of the united kingdom.

It has been found on the other side of the Atlantic ocean, in Newfoundland, Cape Breton, Canada, and some of the New England provinces. Mr. Jefferson informs us, in his Notes on Virginia*, that the country on James river, from fifteen to twenty miles northward and southward, is replete with mineral coal of a very excellent quality. In the western country, he says, coal is known to be in so many places, as to have induced an opinion, that the whole of the tract between the Laurel mountain, Mississippi, and Ohio, yields coal. It is also known in many places on the north side of the Ohio. The coal at Pittsburg is of very superior quality. Dr. Anderson† states, that coals have been discovered also at Madagascar. At the Cape of Good Hope, where fuel is very scarce, we learn, by the accounts of Mr. Barrow‡, that coal has been lately discovered *coming out to day*, at the depth of two feet, along the banks of a deep rivulet flowing out of the Tygerberg hill.

In China, it is probable that coal was discovered long before it was known in the western world. About the middle of the thirteenth century, a noble Venetian, in his description of China‖, observes, " That through the whole province of *Cathay*, certain black stones are dug out of the mountains, which, being put in the fire, burn like wood, and, when kindled, they continue burning a long time, insomuch that if they are lighted in the evening the fire will keep alive during the whole night."

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* Notes on the State of Virginia, by Thomas Jefferson. London, 1787, p. 43.

† Anderson's Dictionary of Commerce; vol. i. p. 229.

‡ Travels in Southern Africa, by Capt. Barrow.

‖ Marcus Paulus Venetus. Purchas's Pilgrimage, vol. iii. p. 88.

Coal is found at various depths in the earth, and interposed between strata of different kinds. The veins of coal also vary considerably in the thickness of the vein; sometimes being many yards thick, and other times being merely a seam, little more than an inch in thickness.

The strata, which are generally interposed between the gravel, clay, sand, and mould, at the surface, and the coal itself; or which appear to be most generally connected with coal, have commonly a considerable degree of hardness: but they differ from each other very much in this respect, as well as in their thickness and their other properties. Do not fear that, by endeavouring to furnish you with some information respecting these several strata, I shall engross your time with the consideration of matters irrelevant to the grand object of our inquiry; on the contrary, be assured that it will derive from this investigation a considerable degree of illustration.

Sand-stone is among the uppermost of the solid strata. It is of a granulated substance, of various degrees of hardness and coherence; and is formed by very small grains of various siliceous stones, and frequently of mica, imbedded in a calcareous, argillaceous, or even a siliceous cement. In the latter instance they possess a great degree of hardness; the hardness is also considerably increased, in every species, by the admixture of iron which has undergone but a slight degree of oxygenizement.

Rubble-stone is a species of sand-stone, containing also a bluish slaty substance.

Lime-stone also frequently occurs among the superior solid strata, and like the former is also found among the inferior strata. It exists in very considerable varieties of hardness and coherence, breaking with various kinds of fracture, according to the substances which unite with the calcareous matter of which it is chiefly formed.

Free-stone, so called from its breaking or working in all directions with the same degree of freedom, and which is a compact lime-stone of an earthy fracture, is often met with in the search for coal. When it is of a very considerable degree of thickness, it obtains, in many coal countries, the name of *post-stone*, of which four varieties occur, named, according to their colour, *white*, *grey*, *brown* or *yellow*, and *red post*. These are sometimes called by the colliers *bands;* thus they will say *grey free-stone bands*, but the Scotch colliers term them *grey fekes*.

Whin-stone, Basaltes, and other stones whose hardness is such that their angular parts will scratch glass, and whose fracture exhibits an appearance so much resembling that which might be expected from sand half vitrified, as to have induced many to suspect them to be of volcanic origin, also form strata of considerable importance, from their hardness and quantity, in most coal mines. These are commonly called *cockle* in Cornwall, and *skurdy* in the north of Scotland.

Iron-stone, called also *metal-stone*, and by the Scotch colliers *dogger band*, is a stratum, which is generally next above the roof of the coal. It is very hard, compact, and solid, and of considerable weight. Its colours are various shades of brown and grey, and sometimes it is nearly black. It evidently consists of argillaceous earth impregnated with iron. Nodules of a richer ore of the same metal are frequently contained in it. These are called *ball iron-stone*, *cat's-head*, and *doggers*. Masses of pyrites are also frequently found in this stratum.

Shale, or slate-clay, called also *shiver*, *black metal*, and *bleas*, and by the northern colliers *blae* or *till*, often also forms the roof of coal mines. It is generally bluish, blackish, or of a reddish grey. It is frequently marked with impressions of vegetables. It breaks into long thin shivery lamina, and is very friable. It readily resolves, on being immersed in water, or even on exposure to the air, into a fine soft clay. It contains a portion of bituminous matter, and generally has an unctuous feel, on which account the Scotch colliers term it *creeshy blaes* or *greasy blaes.*

Not only do these strata vary in different districts, but, even in the same district, a considerable difference will sometimes be found in the strata; and these differences may even arise from varieties frequently occurring in the same species of strata, from which may result several distinct strata differing in colour, quantity, coherence, &c., whilst a stratum of another kind may occur only once or twice.

The following Example of the different Strata of Earth, Stone, and Coal, in a Coal Mine to the West of Dudley, in the County of Stafford, will serve to give you an idea of the manner in which they occur.

Strata.		Ft.	In.
No. 1	Yellowish clay, immediately under the mould	4	0
2	Bluish clay	5	0
3	———— more compact and firm, called *clunch*, and bearing the impression of plants	24	0
4	———— softer than No. 3	9	0
5	A bank (stratum) of grey stone	4	0
6	Whitish yellow clay	21	0
7	Hard grey rock, with faint impressions of vegetables	75	0
8	Clunch, in which fossil plants are found	5	0
9	Bench or bank coal (black and glistening)	1	0
10	Slipper coal (abounding with coals)	3	0
11	Spin coal (a blacker and glossy coal)	4	0
12	Stone coal (pretty like Cannel coal)	4	0
	These four beds were separated by BATS, a hard stony earth	1	0
13	Dunrow bats		
14	Grey iron-stone, called grey-bench	0	1
15	Bluish bat, in which is found iron-stone	0	3
16	Blackish and hard iron ore, called white-row grains, the grains being like shot	1	3
17	Hard grey iron mine, spotted with white, called mid-row grains	0	2
18	Gublin bat, a black fissile substance, an iron ore, in which a bituminous shivery earth abounds	0	2
19	Gublin iron-stone (an iron ore, hard, blackish, and spotted with white)	0	9
20	Bat, resembling No. 18	1	6
21	Cannoc iron-stone, hard and grey	0	6
22	Bat, somewhat harder than No. 20	1	0
23	Rubble iron-stone, in grains, grey and hard	0	6
24	Table bat	2	0
25	Foot coal, a coarse sort	1	0
26	Bat, black, brittle, and glistening	4	0
27	Heathen coal	6	0
28	Bat coal, an ordinary coal, in a thin bed, and does not burn well	0	1
29	Bench coal	2	0
30	Bat	0	6
		180	6

In the foregoing table are several terms, which, being provincial expressions, may not be generally comprehended. They will, however, be understood, probably, sufficiently well for the present intention: it, however, may not be amiss to observe that clunch, in that part of the country to which the above table refers, represents the firm blue clay of Wallerius *(argilla plastica particulis subtilioribus)*, which is generally used for tiles: and in Cambridgeshire the same term is employed to describe a white hard clay, containing sand and small stones.

The line formed by the bearing, or laying of one stratum upon another, is termed THE PARTING, and according to the facility of separation it is named a *good parting* or a bad parting. Sometimes the two strata are so closely conjoined as to render their separation very difficult, this is termed a bad parting. On the other hand, a thin dusky laminated matter is sometimes interposed between the two masses, whereby a good parting is formed.

Besides these partings of one stratum of coal from another, each stratum will be found disposed to part, at numerous secondary divisions or partings, which run parallel to the former, but are necessarily not so visible nor so strong. Other divisions or lines of separation occur, which cross the former horizontal ones in nearly a perpendicular direction; these are called BACKS. These are crossed too by others, at right angles, also in a direction approaching to perpendicular: these are called CUTTERS. The facility of separation at these lesser lines of partings will often be found to be promoted by a film of pyritous, earthy, and even stony matter having formed the substance which is interposed at these partings.

In the parting between the superior part of the mass of coal, and the impending stratum or *roof of the mine*, very considerable differences occur. Sometimes the parting is very difficult and bad, from the closeness of their union. At other times the head of the mass is sprinkled with a powder like soot, or powdered charcoal.

found that they will be thrown up again as much by one slip, as they appear to have been thrown down by the other. It sometimes happens that all the slips are *down-slips*, the strata seeming to have sunk lower in each succeeding slip. These slips differ very much in their width, as well as in the matter with which they appear to have been filled. Some, which are wide, are filled with adventitious and heterogeneous matters; and others with soft argillaceous matters. Other slips are seen, in which, although the strata are thrown a great many fathoms off the ordinary level, the two sides of the fissure are found, in some places, quite close together. In these perpendicular fissures, or *rake veins*, as they are called by miners, a confused mass of heterogeneous matter, solid whin-stone, spar, ores, and metals, and particularly sulphurets of metals, are frequently found; very large ribs of spar, and of pyrites, being very frequently thus disposed. A DYKE is a separation or chasm in the coal and accompanying strata, which differs from the slip, chiefly in bearing the marks of a mere fissure or separation; the coal seams and other strata being not thrown off their levels, as in slips; and the heterogeneous matters with which the chasm has been filled, bearing more plainly the marks of having been brought there by water.

In slips the coal metals have a *vise*, which is the *vestigia* of the coal, and which leads upwards, or downwards, to the separated stratum of coal; but in dykes there is no such vise leading through to the other side. Sometimes the crack or chasm in the coal, and in the accompanying strata, resembles the dyke in every respect, except that the foreign matter is not indurated as in that of the dyke, but always continues loose, and generally very wet. These are called GALLS or GASHES.

When the separation is not very considerable, and the strata on each side the fissure maintain their original position, it is called A HITCH. In some places, without any apparent cause, the coal about fifteen miles over every way. Frequently, Mr. Williams observes, the seams of coal rise up to day, and then seem to decline a little way down from the surface of the earth to a sufficient depth to be preserved fresh and good, even in full perfection, until the exigencies of society have occasion for them; and that, when they have declined so far, they then become quite flat, and afterwards rise again upon the opposite side of the coal field, with an opposite dip and rise, and so form a great trough, resembling a valley; which is, he remarks, one of the best similitudes of the position of the seams of coal in a coal field that can be imagined.

Yours, &c.

LETTER XVII.

PARTICULARITIES OBSERVABLE IN DIFFERENT COAL-PITS.... CANNEL COAL....PYRITES, &c.

Having thus endeavoured to furnish you with a compendious account of the particular circumstances which accompany the disposition of coal, I shall, for the sake of supplying a few more points of comparison, lay before you a sketch of some of the more interesting mines of coal; that you may be the better enabled to determine how far the attempt to account for their existence agrees with the phenomena which nature presents to our observation.

At Bishop-Sutton, near Stowey, in Somersetshire, the first solid vein is called the stinking vein, from its peculiar impregnation with bitumen; and at about seven fathom occurs a stony stratum, called, in that part of the country, *cats-heads*, from its containing the substances so called. This vein is two feet in thickness, and at about five fathom lower down is found, what is called the three-coal vein, formed of three different sorts of coal; a stony bed, between one and two feet in thickness, being between the first and second vein, but the second seems to lie on the third, with hardly any parting between, being in the whole about three feet deep. At eight or ten fathom beneath this is the peacock or *peaw* vein of coal, the surface of which is marked with eyes, diversified with colours like the eyes of the peacock's tail. The uppermost surface of this coal is intermingled with fossil shells, and the vestiges of fern. At about five or six fathoms beneath this vein, is the smith's vein, so called from the use to which the coal is chiefly applied. A little lower than this is what is termed the shelly vein, and about ten inches lower than this is a vein too indifferent to be worked.

At Whitehaven, at the depth of forty-two fathoms, the roof of the coal is met with, being a black rock six inches thick, which has been cleft into regular squares about six inches in diameter, having an appearance similar to a piece of tesselated pavement. From Whitehaven to below Thoresby are pits of coal of very considerable depth. At Newcastle upon Tyne, as I am informed by Mr. Robert Eddington, the ingenious author of an " Essay on the Abuses of the Coal Trade," there is a coal-pit, which is an hundred and thirty fathoms in perpendicular depth, and which is worked, at that depth, five miles horizontally, quite across, beneath the Tyne, and under the opposite county of Durham. In Northumberland, towards the more eastern parts, are pits of coal at thirty fathoms depth. With respect to Cumberland, the whole county seems to be a mine of coal and of black lead.

At Newcastle upon Tyne, Staffordshire, and in some parts of Scotland, the strata are chiefly composed of stones fit to be applied to the purposes of building. In Yorkshire, throughout the whole district of Richmond, in Shropshire, and Leicestershire, and in almost the whole of the northern quarter of the island, the coal approaches in its appearance very nearly to bitumen, which has merely suffered induration.

In Lancashire, near to Pendle Hill, is obtained a species of the Cannel coal. In Durham the coal is so near to the surface of the earth, that the wheels of the carriages lay it open to day, in such a quantity, as to be sufficient for the use of the neighbourhood, and to become a valuable branch of income.

At Widrington, near Berwick, bordering upon Scotland, is a coal pit, the strata of which, according to Mr. Stracey, are thus disposed. A bed of clay of four yards in depth is first dug through, when a seam of coal is found about six inches in thickness. The next two fathom are filled by strata of free-stone, whin-stone, and potters earth; then appears a stratum of soft white stone, and then coal for about three feet and nine inches in thickness*.

At Auchenclaugh, six miles to the east of Kilsyth, there is a coal mine eighteen feet in thickness.

At Mall-traeth Marsh, about the midway between the sea and the farthest inland points of the marsh, they find, whilst digging for coals, a perfect sea shore, with all the marks of it, as pebbles, shells, &c. under five or six yards of pure sand†.

In Scotland, where the coal exists very plentifully, it is in general of an exceeding good quality, being, like the Cannel coal of Lancashire, almost purely bituminous.

In a quarry about a quarter of a mile above Roslin, and also near Auchindinny, upon the north side of the river, is a regular, continuous seam of coal, only about an inch, or an inch and a half thick, with very strong thick beds of post stone above; and there are also several thick seams of coal, both above and below this thin one.

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* Philos. Transact. 1725.

† Rowland's Mona Antiqua, p. 16.

be remembered, does not enter necessarily into the composition of the coal, any more than the metal does, except that both are deposited together in the numerous small intersections which every where divide the substance of the coal; and frequently they are deposited in very splendid pyrites, on the surface next to the superior accompanying stratum. Thus at Whitehaven, where the coal pits are very deep, the surface of the slate, which forms the roof to the coal, is entirely covered with pyrites.

As I shall have repeated occasion to refer to the pyrites, I will here remark, that pyrites, marcasites, or metallic sulphurets, those bodies which generally manifest a metallic lustre, and possess at the same time a crystallised form, are compounds of sulphur and metal, frequently of copper and lead, but, by far, most generally, of iron. By slow decomposition they derive oxygen from the air, which, uniting with the sulphur, forms sulphuric acid, which then acts on the metal, and forms with it a sulphate, or solution of the metal in sulphuric acid.

Besides these substances, analysis demonstrates that several of the acids, in combination with some of the alkalies and of the earths, but chiefly with the latter, exist also in coal. These acids are also found in the accompanying strata of coal pits, and sometimes add to the pecuniary advantages derivable from those real mines of wealth.

The earth, or stone, accompanying coal, is frequently employed for the formation of alum, it possessing almost all the principles of that salt. By long exposure to the air and moisture, or by a judicious application of heat, and a subsequent use of moisture, the sulphuret of iron undergoes the following change: the sulphur becomes oxygenized; and the acid thus formed, uniting with the metal, forms a sulphate of iron. A second employment of heat, and of subsequent moisture, produces such a change on the iron, that it is no longer capable of being held in combination with the acid, which therefore unites with the clay. An addition of pot-

According to Mons. Morand, eight pounds of Scotch coal produced thirteen ounces of a saline water, one ounce of a volatile salt, six ounces of dark-coloured oil, resembling petroleum in colour and smell, and left six pounds and a half of cinder. He suspects that the oil of coal obtains its colour, and perhaps its smell, from a small portion of sulphur which enters into its composition, since he finds silver is blackened by it in the same manner as by the balsam of sulphur, which is a combination of sulphur with oil.

Yours, &c.

LETTER XVIII.

BITUMINOUS FERMENTATION....COMPARED WITH THE OTHER SPECIES OF FERMENTATION....BITUMENS, THE RESULT OF THIS PROCESS....PEAT, A VEGETABLE FOSSIL, THE FIRST PRODUCT OF THIS FERMENTATION.

HAVING supplied you with the most interesting particulars, respecting the properties of bituminous substances, and the situations in which they are found, I shall now endeavour, aided by the observations of those who have preceded me in this path of science, and by the light yielded by the later discoveries in chemistry, to ascertain their actual origin, and to propose a conjecture as to the nature of that process which has been instituted for their formation.

A careful investigation of the subject has led me to believe, that the mineralisation, or petrifaction as it is generally called, of vegetable matter, as well as the formation of every bituminous substance, is primarily dependent on that process, on the accomplishment of which the formation of peat also depends. This process, therefore, must necessarily demand a strict attention; and our enquiries will, I doubt not, be sufficiently repaid on the discovery of the important offices which this process performs.

We have already seen, that vegetable matter, deprived of life, suffers, on the surface of the earth, a certain decomposition, by which some of its principles, becoming volatilised, are diffused in the surrounding atmosphere, whilst others enter, on the spot, into new combinations, and there form a substance called vegetable mould, replete with all the principles necessary to yield the proper pabula to a succeeding race of the same class of beings. But other, and very different changes to those which take place on the surface, were necessary to be decreed, for those vegetable substances which are buried far beneath the surface of the earth.

In some cases, it is highly presumptive to measure the wisdom and providence of omniscience, by our narrow judgments; and it is bordering on profanation to point out, as the wonderful contrivance of the deity, those arrangements which may be only the creatures of our own fancy and imagination. But I trust that, in this conjecture, I shall not err. The path of nature appears here too plain to be mistaken. The resolution of vegetable matter into mould fit for the future growth of vegetables is the result of a design, the end of which is evident. But when vegetable matter is deposited at depths lower than the roots of vegetables ever reach, a conversion into a substance of this kind would be useless; and nature, it must be remembered, does nothing in vain. Another process is therefore instituted; and instead of a substance being produced, calculated to promote vegetation, where vegetation never takes place, a substance is formed, differing in its nature, and varying in its properties, from all others.

The process by which this substance is formed I shall take the liberty to consider as of the fermentative kind, and shall distinguish it by the name of BITUMINOUS FERMENTATION; defining it—*A fermen-*

tation peculiar to vegetable matter placed in such situations, as not only exclude the external air, and secure the presence of moisture, but prevent the escape of the more volatile principles; and which terminates in the formation of those substances termed bitumens.

Having here distinguished this process, for the first time, as a species of fermentation, its right to such a distinction ought to be ascertained as soon as possible; but, as the circumstances on which its claim depends are to be found in the history of the phenomena it produces, and of the results of its operation, we will first hasten to their consideration.

In a process carried on in the recesses of the earth, or, at least, in situations from which our observations are excluded, it is not to be expected, that a complete history of all the phenomena which occur during the whole of the operation can be possibly made out. To furnish a satisfactory account, we must have recourse to inference and analogy; thus aided, we may, perhaps, with only the product of the operation before us, be enabled to form well-founded conjectures on the phenomena which have actually taken place.

Almost all vegetable matters manifest a strong disposition to decomposition, when the separation of their integrant molecules is aided by the interposition of the particles of water; and particularly if, with this, is combined the powerful energy of caloric. If this latter agent be employed, only in a low degree, an intestine motion among the integrant molecules takes place, the equilibrium by which that particular mode of composition was preserved is broken, a separation of the constituent principles takes place, they become influenced by new attractions, and then enter into new combinations and modes of existence. Thus a resolution of the original compound is effected, and new substances are formed, differing much in their physical, as well as their chemical properties, from the substance from which they have proceeded. One particular point in which they almost always differ may be here very remainder that the accomplishment of this process is effected. In the acetous fermentation, this escape of the volatile parts is continued through the whole of the process, and occasions the great difference which exists between the two products. In the first of these species of fermentation, carbon, that principle which always seems to affect that mode of combustion, observable in ignited charcoal, where flame is not present, is, we have remarked, dissipated in very large quantities, by which its dose in the mixture must be considerably diminished; whilst, should hydrogen even be supposed to escape in a similar proportion, still, from the decomposition of the water, sufficient of this principle, which I will call the principle of inflammability, will be yielded, to give the spirituous and very inflammable product which we find to be the result of this process. In the latter of these species of fermentations, in which the dissipation of the volatile matters are carried to the utmost extent which the degree of temperature will admit, the mixture appears to be deprived of almost the whole of its hydrogen; except, perhaps, just so much as is left in combination with the colouring principle, and the water, whilst the oxygen is attracted, nearly in the same proportion, by the carbon from the atmosphere, and from the very considerable dose of this acidifying principle; and, from some peculiar modification of their union, the product, *vinegar*, results, possessing a high degree of acidity, but not the least degree of inflammability.

We will now examine the changes which may be expected to result from the decomposition of vegetable matters placed in subterranean situations, and considering these, with the properties which are possessed by the supposed product of the bituminous fermentation, shall be enabled, especially by recollecting what has been just said of the other species of fermentation, to determine whether it is right to admit of the existence of such a species of fermentation or not.

Secured on every side by the surrounding earth, the mass of vegetable matter is preserved, as it were, in a well closed vessel; hardly any escape being permitted to any of its more volatile particles, nor any admission of extraneous matters allowed, except of such as are introduced with the water which may insinuate itself by soaking through the interstices of the earthy particles, composing the several strata which inclose it. It is decreed that a strong disposition to separate, and to unite in another order, shall secure the necessary decomposition of dead organised matter, which, according to the economy of nature, is but to possess a short and transient cohesion. Agreeable to this law, this mass of vegetable matter, now deprived of the energy of vegetable life, must undergo some change; but, from the closeness of its preservation, it cannot admit that escape of the gaseous matters on which the commencement of the vinous, acetous, or putrid fermentation depends: another process is therefore instituted. The hydrogen, carbon, and oxygen are disengaged from their former attachments, but, being prevented from flying off in a gaseous state, are obliged again to unite, and to enter into new combinations. Under these particular circumstances, a substance may be expected to be formed containing a considerable portion of these principles so abundant in vegetable matter. In this respect, there undoubtedly may be discovered a remarkable agreement between the supposed product of this fermentation, and the hypothesis by which its formation is attempted to be explained; since, in all bituminous substances, the abundant existence of these three principles has been sufficiently proved by analysis.

In this, as in every other species of fermentation, a considerable difference may exist, as to the degree of perfection to which the process may proceed, and, of course, as to the degree of perfection which the product may possess. Thus I expect to shew, that, according to length of time, exclusion from the air, and the existence of other favourable circumstances, will these bituminous substances be found, in their several approaches to that state to which the laws of nature seem to have particularly destined them.

Peat, that combustible and inflammable substance, generally found in considerable masses at a little depth beneath the surface of the earth, possessing chemical properties essentially different from every other substance which has not derived its existence from the same origin, appears to be the first product of this kind of fermentation, and to have been formed in situations not favourable to the rapid completion of this process. The celerity with which this process is accomplished must depend on the closeness with which the gaseous principles are secured; but it should be considered, that such peat-bogs, as are comparatively but of modern formation, are covered by a coat of vegetable mould, in an humid state, of no considerable degree of thickness, and therefore the escape of the more volatile principles, and the admission of atmospheric air, is only partially prevented; the process must therefore be carried on with much less effect than in those cases which will be hereafter mentioned, where vast masses of vegetable matters have been suddenly buried under a considerable thickness of earthy deposition.

The abundance of hydrogen, carbon, and oxygen, in peat, is demonstrated by its analysis. By the early analysis of Schoockius we learn that it yields an oil much resembling the oil of amber, with an acid liquor. Mons. Fourcroy relates, that, on exposing peat to the action of heat in a distillatory apparatus, a yellow or reddish fœtid water is obtained, an oil of a most disagreeable odour, with carbonate of ammonia, and carbonated hydrogen gas, also smelling most disagreeably; a coal being left which is frequently pyrophoric, and which yields, after incineration, muriate and sulphate of soda and of pot-ash, mixed with the phosphate and sulphate of lime, and with the oxides of iron and of manganese*.

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* Syst. des Connois. Chem. tom. viii. p. 233.

The prevalence of hydrogen in this substance is fully displayed by the foregoing analysis, since not only enough exists for the formation of this peculiar oil, but a considerable quantity of this principle is also disengaged in a gaseous form: the agreement, therefore, between this substance, and what might, *à priori*, have been supposed would be the product of vegetable matters placed under these particular circumstances, appears to be evident. The original mode of existence which belonged to this substance is sufficiently marked, by the great quantity of vegetable substances which are found in it, which have not suffered such an alteration as to hinder the immediately tracing of them to their true origin. That this substance has been subjected to the influence of the two circumstances which seem essential to this peculiar fermentation, the presence of moisture and subterranean situation, must appear so plain from the descriptions you have already had laid before you, of the state in which peat-mosses are found, that, on this point, not a word need be added. Peat, therefore, I presume, we may regard as a vegetable secondary fossil; having been formed from vegetable matter, changed in its nature and properties by a certain fermentation, which has been carried on in the mineral regions.

Yours, &c.

LETTER XIX.

FOSSIL TREES, IMBEDDED IN PEAT, HAVE UNDERGONE THE BITUMINOUS FERMENTATION....THE CHANGES WHICH MOW-BURNT HAY UNDERGOES, SOMEWHAT SIMILAR TO THAT PRODUCED BY THE BITUMINOUS FERMENTATION.

The fossil trees which are so frequently found imbedded in peat, may also be considered as vegetable fossils; and as they appear to have undergone exactly the same kind, and the same degree of mineralization with peat, their consideration along with that substance seems most eligible.

These trees, as appears by the accounts already given, are almost always found to have preserved their original form and structure so exactly, as frequently to render it easy to discover what species of trees they are, even in this their mineralized state. When first found, these trees are generally of a dark brown colour, manifesting, as has been already mentioned, the exact form of the original tree; but so soft, as to be capable of being deeply cut into by the stroke of a spade; and also of so spungy a texture, as to allow a very considerable quantity of water to be squeezed from them, even by a moderate degree of pressure. So tenacious are they of the water they have thus imbibed, as still to retain a very large portion of it, even where great pains have been taken to procure its expulsion.

But when, after long exposure to the air, this water has been evaporated, the substance of these fossil trees assumes different degrees of solidity, dependent on the state in which the wood existed at the time of its exposure to the bituminous fermentation, and on the extent to which this operation has proceeded. Should the texture of the wood have been loosened by previous decay, it will, in its bituminous state, when dry, be found to be in a loose shattery state; the fibres being hardly discoverable, owing to their having concreted into irregular fasciculi. The appearance which such pieces exhibit may be conceived from the specimen delineated in Plate I. Fig. 1.

But, on the contrary, if the wood had endured little or no previous decay; nor has suffered any loss of substance, from the agitation of the water in which it has laid, and has undergone the same degree of bituminization which peat in general has suffered, it will, when dried, not only possess its pristine form, but almost its original degree of hardness. Slips of this bituminized wood will flame, when lighted, like matches made from the fir or pine tree; which circumstance has occasioned some confusion, some having asserted that the trees from which these slips have been taken must, of necessity, have been of the resiniferous kind, from their possessing so great a degree of inflammability after ages of immersion in water. This phenomenon, however, is more easily accounted for, by considering that this substance no longer possesses any of the original compound constituents *(materiaux immediats)*, of which turpentine is one, but that the inflammability depends entirely, on the wood being now converted into a bituminous matter; which circumstance is evinced by the particular odour, and other peculiar circumstances, which accompany the combustion of this substance.

Bituminous wood, sometimes possessing a considerable degree of closeness of texture, has been very advantageously employed for many of the purposes to which ordinary timber is generally appropriated. From its adoption for such purposes an observation has been made, which deserves, in this place, particular notice. The experience of the workmen has led them to observe, that this species of fossil wood resists the action of water much longer than other wood; they therefore choose to employ it in those situations which are most exposed to injury from that element. Here we plainly perceive an instance of the powerfully pervading influence of this species of fermentation—trees so little altered in their structure as to bear all the ordinary operations of hewing, &c. in the same manner as common timber, are found to be so far bituminized, to their very centre, as to have become, when dried, in a considerable degree impenetrable to water; a property possessed by all bituminous matter, after having been once dried, in proportion to the degree of perfection to which their bituminization has proceeded.

That the leaves, and other soft parts of plants, should suffer considerable change by this, or by any other species of fermentation to which they are subjected, is by no means difficult to understand; but that large solid trunks of trees should thus be penetrated, by this peculiar influence, to their very centre, and that too in those kinds of wood the substance of which is naturally very dense, cannot but excite interest and surprise. To account for this astonishing effect, it is necessary to consider the powerful agency of water; which, either existing in a separate state, or as one of the constituent parts of the substances exposed to this species of change, appears to be as indispensably necessary in this, as in all other fermentations. It is well known that, by the long continued immersion in water of a piece of timber, the particles of water may be made to insinuate themselves through every part of it; and when the water is impregnated with the leaven of this fermentation, this will of course be conveyed to every part, and thus may we account for so wonderful a change being effected through the whole substance. Hereby we discover that this effect, so astonishing at first view, is accomplished by this two-fold action of the water; first, by separating, by its interposition, the integrant molecules of the wood; in producing which effect it is perhaps aided by the combined action of a portion of caloric; and, secondly, by conveying to every point of the vegetable substance the leaven of the bituminous fermentation; by the active energies of which fermentation the whole mass of solid wood is made to undergo an actual conversion, and to pass from the state of wood to that of bitumen.

This particular species of fermentation may be illustrated, by considering the phenomena which result from vegetable matter being placed in such circumstances, as we have assumed necessary to the production of this fermentation, excepting only that of not being in a subterranean situation. Should we find that vegetable matter thus disposed undergoes a somewhat similar fermentation, which produces a change approximating to that which takes place in what I have termed the bituminous fermentation, we shall have another presumptive evidence of the propriety of distinguishing the process by which peat is formed, as a species of fermentation.

The situation in which we find vegetable matter thus disposed, and in which the effects are immediately under our own examination, is that in which the various species of grass, &c. are so closely stowed together, and in such quantity, that the weight and thickness of the superior layers must totally prevent all access of the external air, and any escape of the separated gases. You must have already perceived, that I here refer to the process employed in hay-making; and you well know, that when this operation is conducted according to the wishes of the farmer, that the saccharine fermentation, or a fermentation nearly resembling it, only takes place; and the grass is changed into *hay*, which possesses a peculiar fragrance and sweetness. But should the grass, at the time it is heaped together, unfortunately retain too much water, very different effects will follow: heat will be rapidly evolved, and a dense vapour will be seen to exhale from the mass. If the process be stopped in this stage, the mass of vegetable matter will be found to have acquired a very dark brown colour, and a glazed surface, and to emit a strong peculiar odour, resembling that of empyreuma, or of bitumen. In this state it is generally known by the term *mow-burnt hay*. But if the process be allowed to go on, the heat soon considerably augments, the vapour assumes the form of smoke, and, at length, actual flames break forth, and the whole mass is presently reduced to ashes.

The remarkable evolution of heat, in the fermentation I have just spoken of, demands an inquiry whether any thing similar ever takes place in the process of bituminization; since, if that be not the case, the parallel would so far fail. But, as the process of bituminization is carried on out of the reach of our examination, it is impossible, as has been already observed, to speak accurately respecting the phenomena which arise during its performance. The following account, however, contained in a letter from Peter Collinson, Esq. to Sir Hans Sloane, among the unprinted papers of the Royal Society, preserved in the British Museum, shews that this phenomenon may arise during this process. You will also perceive that the learned writer proposed to account for its occurrence in a similar manner with that which I have here adopted.

" Our newspapers, printed here, mention the burning of brooks, in the Vale of Good Cheap; but the case is, that some pieces of marshy ground, called brooks, from their watery situation, have flamed for some time; and these they have called *burning brooks;* the parish next adjoining is also called Brooks. The soil is like those parts of Cambridgeshire, where the turf is cut, and very often under water; but this dry season has brought it from very wet to that degree of moisture which often causes hay to ferment and take fire. Accordingly, this fire begins about four feet under ground, just above the water (as appears by digging), and so burns up to the surface, where it flames out, especially if stirred with any thing; and, according to the quantity of roots and fuel it meets with, it leaves strata of black coal, or red ashes. The fire has now burnt for several weeks, and is expected to continue till the rain or springs extinguish it. The same land burnt, in the same manner, about forty years ago. Perhaps this hypothesis, of its kindling by fermentation, may be confirmed by the frequent firing of hay-stacks this year, of which we have had many more instances than in several years before."

Upon the authority of Schoockius, we learn that this species of combustion is no rare occurrence in the peat-pits of Germany. More or less frequently, he says, it happens; but chiefly when the heat has been more violent, and the rains have fallen less plentifully, that either by accident, or by some one's malice, not only the dry peats, but even the marshy earth itself, become drier than usual, is set on fire; when the flame spreads far and wide, occasioning a calamity, not less dreadful to those labourers who dwell at the pits, whose little hovels it lays waste and reduces to ashes, than to those who derive their livelihood from these pits. For this reason, proper watchmen are appointed to go round, not merely to keep it together in heaps, but to be ready to extinguish, in time, the fire which might break out. This they do not so much by water, which is not always found in sufficient quantity, as by smothering it, by turning over it with shovels the adjoining earth. If this be not done, the flames continually acquiring more fuel, the fire ravages, not for a few days, but for weeks and even months, as dreadful experience has shewn, so that the extended plain may be regarded as a lamentable and distressful kind of volcano.

Thus far I may, surely, venture to remark, that analogy confirms the opinion, that peat is the product of a peculiar fermentation.

Yours, &c.

LETTER XX.

EXAMINATION OF OPINIONS, RESPECTING THE ORIGIN OF PEAT.... ABORIGINAL FORMATION....A MARINE DEPOSIT....MINERAL ORIGIN....FLOATING ISLANDS....A RECENT VEGETABLE SUBSTANCE.

ALTHOUGH I encourage the hope, that the circumstances adduced are such as will be likely to be successful, in establishing the opinions I have offered, respecting the origin and nature of this substance; yet something more remains to be done. The opinions already advanced, on this subject, have a claim upon our attention; and although the greater part of them may not require a formal refutation, others will require to be examined, that it may be determined whether they offer a satisfactory explanation of the properties which are possessed by this substance. It is likewise incumbent to determine whether those particular circumstances, which have been supposed most powerfully to support the hypotheses which have been already advanced, militate against, or favour, that which is here attempted to be established.

The first opinion I shall notice is that which supposes peat to have existed, in its present form and state, from the creation of the world. In opposition to this opinion it must be sufficient to observe, that peat is composed of substances which bear the indubitable marks of having existed in another state; also that there exists an abundance of instances of its formation going on, even at the present day.

The hypothesis, which supposes it to have been formed by a bituminous deposit from the waters of the sea, must be rejected, from its being impossible thus to account for the prodigious quantity of vegetable matters, of which it is so evidently composed. The distinctness of vegetable form and structure, which is thus displayed, and which incontestably proves their previous existence in this mass, serves also to refute the opinion, promulgated by Pliny, and adopted by Schoockius and others, of this substance being entirely of mineral origin; and of its being originally formed in its present situations.

Those who have endeavoured to account for the formation of peat, by the sinking of large floating islands, which have afterwards become covered by the accumulation of strata of other earth, appear, certainly, to have mistaken the cause for the effect. This will I think appear sufficiently plain by examining the following very curious account of the appearance of these islands, as well as of the phenomena which precede and accompany their formation, as given by a gentleman who appears to have almost witnessed the separation of these floating islands in the lake of Derwentwater.

The lake of Derwentwater is celebrated for the astonishing phenomena its waters exhibit. At uncertain times the waters of this lake experience very considerable agitations, the waves running to a great height, and forming large white breakers, on which the boats are tossed as though in a severe storm; whilst none of the usual causes of such commotions of water are discoverable. The waves differ from those produced by ordinary causes; not rolling along from one end of the lake to the other; but rising, in mountainous heaps, from ten inches to two feet in height; as though raised by some powerful elevating force, applied underneath: and, in agreement with the idea thus suggested, the people of the neighbourhood term this phenomenon *a bottom wind*. Sometimes the whole surface of the lake is thus agitated, at other times it is only partially affected; and frequently it will strike a boat with so much force, that it will appear as though it had struck against a rock: a very considerable roaring noise often accompanying these surprising appearances.

A phenomenon, not less interesting and astonishing, is the appearance of floating islands on this lake. These rise, at uncertain periods, from the bottom of the lake: sometimes one, and sometimes two have arisen in a year; and, at other times, several years may elapse without their appearance. Their time of remaining at the surface is also very uncertain; some sinking again, within twenty-four hours; whilst others remain for six weeks, two months, or even longer, before they return to the bottom of the lake; which they in general do without having suffered any change in their form: but sometimes they burst, and are so widely rent, that boats can pass between the separated parts. One rose in 1798, which was one hundred and eighty yards long, and fifty yards wide. They sometimes show above a foot high of land, out of the water; and some have been measured which have been seven yards in thickness. The upper part of these masses, for about two feet in depth, is common mud; beneath this it becomes less compact, and the remaining part is found to be formed of decayed leaves and roots of plants and trees.

A pole being passed three or four feet into them, a considerable quantity of air rushes out on its being withdrawn: this air smells like gunpowder; and it is said that, if collected in a bottle, it will take fire if exposed to the flame of a candle*.

The most prominent circumstances in the foregoing relation are, the matter of which these islands are chiefly composed; the gaseous matter which is so plentifully liberated, from an opening made into its substance by means of a pole; and the extraordinary impulse, and agitation by which the water of the lake is affected. These several circumstances we will therefore subject to a careful and impartial examination.

All, except about two feet of the upper part, of these islands, appears to have been formed of the decayed leaves and roots of plants and trees; and such we well know is the appearance which is yielded by peat in certain periods of its formation. Let us now suppose, that after some considerable time, and after having been covered by various strata, this peaty matter should be discovered; it might then perhaps be found to be well-formed peat. Should also any favouring concurrence of circumstances contribute to bring down the history of a floating island having existed on this spot, the vegetables growing on this island might be supposed to have furnished this vegetable matter, now existing in an altered state; whereas we have seen that the greater part of this mass was composed of such matter, at the time it existed as a floating island.

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* Phil. Mag. No. XLII.

This mass, then, of decayed leaves and roots of plants, and of trees, as described by the ingenious observer, was undoubtedly a mass of long buried vegetable matter, part of a stratum of peat, passing through the bituminous fermentation. The opportunity of its separation having been given, by the superincumbent strata having been so reduced by the excavation which formed the lake, as not to leave a sufficient thickness and strength to resist the expansive powers of the detached gaseous matters, which, for the completion of the process, would have required to have been closely confined.

That this bituminous fermentation was actually going on may be reasonably inferred, from the nature of the gas which was expelled; its peculiar odour, and its imputed inflammability, strongly denoting the presence of hydrogen; the separation, and the subsequent fixation of which have been assumed as important steps in this process. Another circumstance yields very strong collateral evidence, that this operation had proceeded to a certain length. The specific gravity of all bituminous substances is, generally, less than that of the vegetable matter from which they have been formed; this is most certainly the case, when wood has suffered this species of conversion. As this process has therefore gone on, the substance has become specifically lighter, and cavities have been formed by, and distended with, the detached hydrogen, which must have also increased the levity of the mass, and enabled it, even with the superincumbent earth, to make its ascent through the water.

It may also be remarked, that the eruption of these gaseous matters in considerable quantities is sufficient to account for the agitation of the waters, and for the other phenomena which are described as appearing to have been produced by some powerful, elevating force, applied underneath.

Dr. Plot, in his mention of the floating islands of Kinson Pool, in Staffordshire, points out plainly the nature of the substances with which these floating islands are originally composed*. He says, "Of a kind of stringy bituminous earth (roots and oily substances being very buoyant) the floating islands, so much talked of and admired in many parts of the world, are most certainly constituted; whereof there are two about twenty feet broad, but about thirty or perhaps forty feet long, in Kinson Pool, which An. 1680, began, in March, to move from under the hill, on the N.W. side of the pool, and came together, like the *simplegades*, first to the S.W. corner, where, after they had continued about three weeks, they began to move again, and were come in May (when I was there) to the S.E. corner, lying just in the passage of the water, out of the pool, towards the mill. I was also told of such in Aqualat Meer."

The only opinion we have now to examine is one which, if we only regard the abilities, and opportunities of observation, of its ingenious author, must claim our serious attention. The hypothesis to which I allude is that of Dr. Anderson, than whom few have possessed greater opportunities of making observations on this substance, or have endeavoured with more zeal to employ those observations for the public good. He candidly remarks, that, after long and attentive observation, he has only been able to fix upon one fact respecting this subject, which seems to be incontestibly proven—that moss has been produced by a gradual accretion, and has not been created at the beginning of the world, in the state we now find it.

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* The Natural History of Staffordshire, p. 114.

Dissatisfied with previous hypotheses respecting the formation of peat-moss, particularly with that which supposes it to be entirely formed of wood; that which supposes that there may be some kind of extracts from the wood, somewhat of the nature of tan, which, by the medium of water, preserves the fog or moss which grows among the decayed trees, and converts it into peat-moss; as well as that which attributes its origin to a certain state of preservation of the *sphagnum palustre* and some kinds of *confervæ*, the Doctor offers an hypothesis of his own.

Can it be, he asks, that peat-moss, as we find it in its natural state, is, of itself, a vegetable production, not a congeries of dead plants preserved by some mystical influence, as has been generally supposed, *but actually alive*, and in the highest degree of perfection of which it ever is susceptible?

After considering this question with the greatest attention I am capable of bestowing upon it, I feel myself strongly inclined, the Doctor says, to answer in the affirmative, notwithstanding the reluctance I felt at first to give into that opinion, on account of the singular appearance of this substance. In its analysis, recent qualities, decomposition, and final decay, every circumstance tends to point it out as a recent vegetable substance, possessing certain properties of fresh vegetables, particularly inflammability in a high degree of perfection. Its *appearance* is indeed very unlike to those vegetable substances we have been used to observe, and more nearly resembles a mass of putrid vegetable matters than a real living substance. But were, the Doctor observes, appearances alone to be trusted in matters of this kind, many vegetables would have been degraded from that class. The sponge, growing in large irregular masses, more resembles an aquatic excrescence, than a regular organised vegetable production. The truffle, which buries itself in the earth, and never appears at all above ground, would seem to rank rather in the fossil than in the vegetable kingdom. Several kinds of *fungi*, which spring out from wounded trees in irregular lumps, have infinitely more the appearance of a gummy concretion, hardened by the air, than of an organized vegetable. The *licken*, which spreads itself upon the surface of humble plants, bears such an exact resemblance to fragments of decaying leather, scattered on the ground, that it requires a near examination to satisfy an unskilful observer that it is not so. How different are all these from the sturdy tree whose roots strongly grasp the earth, and draw from thence abundant nourishment to support the stately pile which rears its lofty top in wild luxuriance to heaven! Were general resemblance alone to be relied upon, these very dissimilar substances could never be included in the same class. But the forms which heaven has pleased to impress upon organized matter are so infinitely diversified, as to compel us to have recourse to other more accurate means, than general appearances, for ascertaining the nature of these substances which attract our attention. But, from the foregoing observations, it appears, the very criterion by which we can examine this substance, its form and appearance alone excepted, proclaims it to be *a recent vegetable substance, and nothing else.* Why then should we be startled at appearances in this instance, which we have been obliged to disregard in so many other cases of a similar kind?

Having now laid before you the Doctor's hypothesis, in his own words, I will in a summary way state to you the evidence which he adduces in support of it. The solid compact nature of the *moss plant*, as the Doctor calls it, he thinks ought not to be allowed to make against his theory, since the diversities of plants, as to their modes of growth, are so great, as to give us sufficient reason not to think of limiting the laws of nature in this respect. It is certain, that all mosses have been augmented by an increase of real *quick moss*, since their first formation. This augmentation, the Doctor thinks, can have happened in no other way than by its increase, in the manner of growing vegetables, from the time of its first germination till the present hour. But what is the nature of the seed or sperm of this supposed *moss plant;* how it was first planted; in what manner its increment has been effected; or how it should have been determined to grow in one place and not in another; the Doctor acknowledges he cannot pretend to say. But from every consideration he thinks there is much reason to believe, that moss is, in effect, a vegetable matter *sui generis*, which is produced in proper circumstances, though we are as yet ignorant of what these circumstances are; and which continues to increase to an immense magnitude, and to live to an indefinite age; and that in its progress it envelopes trees, and every other matter that comes in its way, which it either consumes or preserves, according as the peculiar nature of each are liable to be affected by its juices; preserving its own properties undiminished, as far as we yet know, until some part of it be cut off from the general mass; after which, as has been said, it evidently ceases to live, and goes through the same process of decomposition and decay as every other vegetable substance.

A similar opinion with this of Dr. Anderson's was entertained by Dr. Plot, who says, that the stringy roots that, together with the bitumen, make up the peats, do never flourish above the surface; and if so, he says, I am confirmed in an opinion, that there are many subterraneous plants not noted, of which I intend a diligent inquiry*.

Without trespassing upon your time with a regular discussion of the Doctor's hypothesis, I will only dwell for a little time on two or three circumstances which I think strongly oppose it.

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* The Natural History of Oxfordshire, by Dr. Plot, p. 16.

Did peat owe its formation to the supposed moss plant, we should not expect to find it, as it often is found, almost entirely composed of other species of vegetable matter. Indeed that which is here supposed to have originated, in one particular mode of vegetation, appears to depend on a certain change which affects vegetable matter in general; but perhaps some parts of the vegetable creation more than others. Thus the *confervæ* and the mosses, and particularly the *sphagnum palustre*, appear to be vegetables which are peculiarly calculated, to suffer a conversion into this kind of substance.

The promptitude with which the species of plants, which I have just enumerated, appear to submit to this change, and their disposition extensively to spread themselves, through every interstice of such peat-bogs as they have possessed themselves of, may perhaps account, in a great measure, for that augmentation of peat mosses, which the Doctor evidently considers as highly confirmatory of his opinion. The Doctor says, " It is certain that all mosses have been augmented by an increase of real *quick moss* since their first formation. This augmentation," the Doctor says, " can have happened in no other way than by its increase in the manner of growing vegetables, from the time of its first germination till the present hour."

To prove that this augmentation is not of *growing peat*, but of vegetable matters under the influence of the common laws of vegetation; and, at the same time, to point out more clearly what seems to me to be the actual circumstance, which appeared to corroborate the Doctor's opinion, I must lay before you the account of this process, as delivered by an eye-witness.

Dr. King, in a paper presented to the Dublin Society, says, " that Ireland doth abound in moss more than I believe any kingdom, insomuch that it is very troublesome, being apt to spoil fruit-trees and quicksets.—This moss is of divers kinds: that which grows in bogs is remarkable; your light spongy turf is nothing but a congeries of the threads of this moss, before it is sufficiently rotten confused direction of its fibres (seen in Plate I. Fig. 2.) shews that, by some process, they have been so much softened, as to have easily admitted a distortion from their natural direction; whilst its chemical properties sufficiently testify its bituminous nature. It appears to have been formed from vast deposits of wood, which have been so circumstanced, as to have undergone the bituminous fermentation to a certain degree; but have not suffered a change sufficient to reduce it to a fluid bitumen. That a portion of it has undergone, even this change, may justly be inferred, from the actual presence of bitumen in different parts of the mass; as well as from the bituminous impregnation of the roof, which impregnation was most likely to have proceeded from the absorption of the fluid bitumen, much of which, from its levity; would rise to the upper part of the closely pressed mass of bituminous wood. The flat shivery state of that which is termed the *knotty-coal*, as well as of that which is termed the *board-coal*, seems to point out, that, after the bituminization had proceeded to a certain point, this substance had been deprived of its moisture; the state in which it is found being exactly that, in which wood, having suffered such a degree of bituminization, might be expected to be found, after having been permitted to become dry. Nor is it an objection of any force that it is now found in a moist state; since, supposing its exsiccation to have been once complete, and the fermentative operation quite stopped, no subsequent addition of moisture could be expected to renew the fermentation, or to soften it so as to render it capable of uniting in a close mass.

Yours, &c.

agree exactly in their nature is well known. Some difference, indeed, exists in the purity of these products; but the same peculiar fœtid oil, and the same volatile acid, which are yielded only by substances of this class, are produced in both cases.

Equally powerful evidence appears to be derived, also, from the fact of pure bitumen being found existing together with peat, in such a mode of combination, as will warrant the conclusion, that the peat has partially passed into a more perfect state of bituminization, so that a portion of it has become perfect bitumen.

In some parts of Aberdeenshire, Dr. Anderson informs us, there is found a certain kind of peat-moss, which, when formed into peats in the common way, are found to be more tender and brittle than usual, so as to break down, during the process of drying, into irregular lumps, called clods. When one of these clods is thrown into the fire, it soon kindles, and burns with a clear bright flame, much resembling that which would be produced by a lump of tallow or butter, in the same circumstances; these are therefore called *creeshy*, i. e. *greasy* clods, though they discover no degree of unctuosity to the sight, or smell, or feel. One of these clods continues to flame for a long time; and the use that is made of them by the natives is to throw one clod into the fire at a time, for the purpose of giving light, and another to supply its place when it is exhausted. This kind of peat, the Doctor acquaints us, is very rare.

The increased degree of inflammability observed in the peat which is here described, can only be accounted for by the presence of bituminous oils; as the clear bright flame, resembling that of a lump of tallow or butter, evidently points out. The presence of any unctuous matter does not indeed appear to be pointed out by any other sensible characters; although, perhaps, even its separation might be obtained by the adoption of proper means.

Monardes, an old Spanish writer on medicine, says, that in Collao, a province of Peru, there is a tract where neither tree nor plant grows, in consequence of the earth being of a bituminous nature. The Indians obtain from this earth a liquor, useful in curing many diseases. Their mode of obtaining it is this:—they cut the earth in turfs, which they dispose on poles, or thick reeds, in a place exposed to the sun, placing beneath them vessels fit to receive the fluid; since the bitumen liquefies, and flows down by the heat of the sun. The turfs, which are thus deprived of their bituminous fluid, are afterwards employed as fuel. In this case, the connection between these two substances appears to be pointed out decidedly, unless it should be contended, that their existence thus together might be only accidental. The frequency, however, with which they are thus found together, the form which the bitumen assumes, and indeed the manner in which it is blended with the peat or fossil wood, strongly declare that the existence of the bitumen depends on the same process as peat.

Schoockius, as we have already seen, relates, that masses of bitumen are frequently found among the peat; sometimes resembling, in size and figure, walnuts, eggs, and pine nuts: and although he is obliged to acknowledge that undoubted pine nuts were also found in the same pits, yet these bituminous masses, found in the same pits with them, were so entirely bituminous, that he could not believe them ever to have been any thing but a mineral production.

Stettuto, describing the fossil wood of Umbria, mentions a white resinous substance, which was found along with it, and which bore the appearance of mastic or frankincense.

Dr. Woodward also mentions, that, along with the hazel nuts and peat, dug up in the Isle of Wight, were pieces of wood, much impaired and decayed, with some small quantities of a black bituminous matter in its interstices. The Doctor also describes a resinous matter, which was found lying between the bark and the wood of some of the trees dug up in Wilmeslow marshes. They call it there, he informs us, frankincense*.

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* Vol. I. Part II. p. 18.

In a considerable stratum of fossil wood, found by M. Fontaine, between Lyons and Strasburgh, several of the pieces were found to be incrusted with a pretty considerable quantity of a substance, which he describes as resembling coarse and imperfect mastic, mixed with other substances, and adhering so strongly to the wood, as to be very difficult of separation. Among the fossil wood of Bovey, as well as among that of Munden, bitumen is also frequently found.

From the observations already adduced, sufficient surely appears to warrant the conclusion, that those substances, which are agreed by all to belong to the class of bitumens, are produced by a farther advance of the same process by which peat is formed. By attending to the properties possessed by these substances, as already described, it must occur to you, that, although they are actually of a distinctly different nature, they approach very nearly, in their chemical and physical qualities, to the vegetable oils and resins.

A circumstance here offers itself to our contemplation, truly admirable and interesting. A principle of action developes itself, totally new to our observation, and almost beyond our powers of comprehension; since it presents to us substances, formed merely by chemical action, emulating in their nature and appearance some of those substances which are only formed by the peculiar powers resulting from organization.

Thus, in the living vegetable, substances are formed, from tasteless and inodorous materials, by the energies of vegetable life, which not only strongly affect the senses of taste and smell, but differ essentially in their properties from the substances from which they have been formed. So the bituminous fermentation, imitating the result of the operation of secretion, forms, from a mass of dead vegetable matter, substances nearly resembling, in most of their properties, the vegetable oils and resins, which perhaps may be ranked amongst the most highly elaborated products of the vegetable kingdom.

Accustomed to witness the production of these substances by the mysterious process of secretion, we find it difficult to conceive their formation by any process, less complex than that which is performed by the appropriate energies of an organized body. Hence has arisen much of the difficulty which has occurred, whilst endeavouring to account for the formation of bitumen, whether solid or fluid. Despairing of ascertaining any particular points respecting its origin, chemists have, until lately, contented themselves with regarding it as a mineral production, elaborated in the deep recesses of the earth, and, of course, in situations which yielded no hope of determining, on what circumstances and principles its formation depended.

Naphtha, petroleum, and asphaltum, have in general been considered as substances entirely of mineral origin; and hence the names they have obtained of *mineral* OIL, *mineral* TAR, and *mineral* PITCH. The French chemists have generally adopted the opinion, that naphtha, and even the other fluid bitumens, are the produce of a distillation, effected by subterranean fires, by which the more subtil parts of certain bituminous matters have been raised or sublimed; these particles having been condensed into a fluid form, by the coldness of the cavities which exist in rocks, and in which they become accumulated.

It undoubtedly may appear, at first view, the more easy and ready way to account for the formation of these matters, by supposing them to be the results of certain subterranean operations, performed on substances which are natives of those regions; than to suppose them to be the results of natural chemical changes, wrought on substances of the vegetable kingdom, by operations carried on in the mineral kingdom. But a discovery, made within a few years, requires to be particularly noticed here, since it cannot fail to illustrate that particular point, which attracts and most deservedly claims our attention.

The discovery to which I allude is one which plainly manifests, that, by the operations of natural chemistry, certain modifications of the principles of bodies take place, by which substances are formed, resembling, in a great measure, the highly elaborated secretions of an animal body. The illustrious Bacon had declared, that pieces of flesh might be converted to a fatty substance by the help of maceration in water. Fourcroy discovered, and his discovery has been confirmed and illustrated by the observations and experiments of several learned and ingenious men in this country, that the muscular parts of animals, after being buried some time where water can have access to them, are changed into a peculiar fatty substance, nearly resembling, in many respects, spermaceti; and to which substance he has given the name of *adipocire.*

Thus we perceive that dead animal matter may, by a process carried on in the mineral kingdom, be converted to a totally different substance, and to one approximating, in its appearance and nature, to another kind of animal matter, the product of a secretory organization. To repeat the numerous experiments by which this has been fully ascertained, would be here out of place. The fact is incontrovertible, and confirms, by analogy, the opinion, that the organised matters of vegetables are likewise susceptible of a correspondent change, if placed under appropriate circumstances.

Another substance, found among the peat, requires also to be spoken of, particularly in this place; since it appears to me, that the ambiguity which obscures its origin is likely to be best removed, by the discovery to which I have just called your attention.

This substance has been hitherto called Mineral Tallow, and is thus spoken of by our justly celebrated mineralogist, Mr. Kirwan:

This is a substance very rarely met with, and therefore very imperfectly known; it was first found by some peasants, on the coast of Finland, in the year 1736. Afterwards a similar substance occurred in one of the Swedish lakes; and, lastly, Mr. Herman, a physician at Strasburgh, discovered a similar substance in the water of a fountain of that city. He describes it as being white, having nearly the resemblance of tallow; feeling greasy, and staining paper, as tallow does. It flames, he observes, with much smoke, and leaves a pretty light coaly matter. It is brittle like tallow, but its specific gravity is considerably less*.

Not unlike to the substance, thus described by Mr. Kirwan, is that which Mr. Jameson speaks of as having been found in the peat-mosses of Scotland†.

A substance similar to that which is here described I have been shewn by Mr. Mawe, of Tavistock-street, in his excellent collection of the bitumens of Derbyshire; in which place this specimen had been found.

Humbold, in a letter to Van Mons‡, mentions, that he had converted the *phallus esculentus* into a substance resembling tallow, by means of the sulphuric acid, and had also made soap of it. Hence Mr. Jameson is induced to ask—May not the mineral tallow of peat mosses be a species of fungus, altered by some natural operation similar to what we have here mentioned.

The close resemblance which seems to subsist between this substance and the adipocire, the want of proof of its vegetable origin, and the rarity of its occurrence, which indeed corresponds with that of animal matter in peat bogs, incline me to imagine that its origin may be attributable to some animal remains, which chance has deposited in these parts, and which, exposed to the action of water, has suffered a change into adipocire. This opinion, I think, is rather countenanced by the instances which occur, in the writings of those who have described the peat pits of various parts of the world, of the existence of animal remains in these subterranean situations.

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* Elements of Mineralogy, vol. ii. p. 47. † Mineralogy of the Shetland Isles, p. 156.

‡ Annales de Chymie, vol. xxii. p. 64.

Thus Dr. Leigh, in his History of Cheshire, relates, that he saw, five yards within the marle, the skeleton of a buck, as standing upon his feet, with the horns on his head, which, the Doctor says, at the time of his writing, were preserved at Ellels Grange, near Lancaster. He likewise informs us, that eight yards within the marle, at Larbrick, near Preston, in Lancashire, the entire head of a stag, of an enormous size, was found. He also mentions, that the head of an hippopotamus was found under the moss in Lancashire.

Mr. A. de la Pryme says*, about fifty years ago, at the very bottom of a turf pit, was found a man lying at his length, with his head upon his arm, as in a common posture of sleep, whose skin being as it were tanned, by the More water, preserved his shape entire; but within, his flesh, and most of his bones, were consumed and gone; an arm of whom, Mr. de la Pryme adds, one of the workmen cut off, and brought home to his master, which is now in the possession of my honoured friend Dr. Nat. Johnson. In the clay which lay over the peat, which was lately dug through, in forming the wet docks in the Isle of Dogs, the bones of horses and oxen were also found.

One more instance remains to be adduced of the formation of oily matter from substances possessing nothing of an oily nature, merely by the aid of a chemical process. In referring to this, I trust a fair opportunity will offer itself of determining whether the formation of naphtha, petroleum, amber, or, in a word, the bitumens, may be attributed to a change induced in vegetable matter culiar properties. Should the oxygenized muriatic be the acid which is employed from the first, an oily matter is generally the result of the distillation; and if the acid be employed in a large proportion, a white, opaque *greasy substance*, of the consistence of half-melted tallow, will be formed.

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* Philosoph. Trans. vol. xxii.

To enable you to judge of the propriety of considering the change thus produced as analogous with the bituminization of vegetable matter, I will briefly state the more generally received opinions, respecting the circumstances on which this conversion of alcohol into ether depends. Laudet and Dabit found, that the addition of oxygen was necessary to the formation of ether; and they discovered, that by employing the oxide of manganese, with the sulphuric acid, this acid was not decomposed, as would otherwise have been the case; but, that the oxide was deprived of a part of its oxygen, and a greater quantity of ether than usual was obtained; no gas coming over, and no charcoal being deposited during the distillation. They therefore concluded that ether contained a smaller proportion of hydrogen, and a greater proportion of oxygen and carbon, than alcohol. Fourcroy and Vauquelin, on the other hand, supposed ether to contain a greater proportion of hydrogen and oxygen, and a smaller proportion of carbon, than alcohol. Thus differing in their opinion as to the proportion of the respective principles; but agreeing, that ether is a substance formed by a new combination of the same principles of which alcohol is composed, but in different proportions*.

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* May not the formation of ether be still better understood by adverting to one important fact, that the solution of carbon in hydrogen is promoted by the presence of oxygen, as is the case in carburetted hydrogen gas? May not, therefore, the addition of the acid or the oxide to the alcohol, by furnishing an increased proportion of oxygen, enable the hydrogen to retain more of the carbon in solution, and thus produce an approximation to an oleous state? In confirmation of this opinion, it is to be considered that, by the addition of merely oxygenized muriatic gas to carburetted hydrogen gas, an oily fluid is formed; and that by the employment of the same acid, in a more

Having thus furnished you with the particulars of that chemical process by which an oil is formed from substances which would not *à priori* have been expected to yield it, we will now endeavour to ascertain how far this process resembles the presumed process of bituminization. In the first place, then, the substances acted upon, by the supposed bituminous fermentation, as well as by the vinous fermentation, are the same—dead vegetable matter. Secondly, as in the vinous fermentation, so in the bituminous fermentation, a peculiar acid and a peculiar combustible substance is formed; those of each process resembling each other in their component principles: this resemblance being particularly close between the combustible substances resulting from each process: each possessing a high degree of levity and inflammability; each being formed of hydrogen combined with a large proportion of carbon and of oxygen, and each manifesting, that the principles of which they are composed are not in a very intimate state of union.

I am anxious, before I conclude this letter, to place before you some of the reasons which have induced me to suppose the ligneous substance to be that part of vegetables which is most particularly acted on, by the species of fermentation which I have assumed; as well as to point out to you a circumstance, which, in my opinion, yields strong, I had almost said internal, evidence of the necessity of such a species of fermentation.

powerful manner, an actual tallow like grease is produced. Another consideration, which seems to corroborate this opinion, of the different steps of this progress to an oleaginous state, depending on certain added proportions of carbon, combined with oxygen, is, that oil itself, the *ultimatum* of this process, holds so considerable a portion of carbon, that this principle constitutes a large proportion of every one of its products, which are carburetted hydrogen, carbonic acid, and charcoal; whilst the quantity of oxygen which it contains is also so great, that it manifests a degree of acidity, in a very short time, merely by the addition of what it attracts from the air.

So generally is the ligneous substance diffused, through the vegetable system, as to render it, perhaps, the most abundant of the compound constituents of vegetables. It not only forms almost the whole of the bulk of the trunks and boughs of trees, and shells of fruits; but it also forms a great part of the husks, and lanuginous coverings of seeds, as well as of the epidermis of leaves, &c. The quantity in which it exists agrees therefore with the abundance of bitumen which seems to be yielded by that species of fermentation, to which I have presumed that vegetables are subject; and it is also worthy of notice, that the substances, which have been just described, as containing a predominating proportion of the ligneous part, are those substances which are most frequently found in a bituminous, or in a mineral state.

The contemplation of nature teaches, that there exists a regular system of dissolution and renovation, through all her works; and that there are certain laws, according to which substances are forced to quit one form of existence, and take on another; their principles entering into new combinations, and forming other substances equally necessary in the œconomy of nature. Thus is constituted the never-ending chain of varying existences, in which, though each link differs from the rest, yet such is their symmetry and proportion, that they form a whole, in which beauty and utility are eminently conspicuous. But when we view the chemical history of the ligneous matter of vegetables, a link appears to be lost, and the chain broken; for whilst other substances yield either to the vinous, or to putrid fermentation, the ligneous, we are told, seems to resist all nature's efforts to force it into a new mode of existence. So intractable does it appear, that it is esteemed the most insoluble and unchangeable of all vegetable substances. If wood be exposed in a close vessel to the destructive action of fire, so little of the ligneous substance is lost, that a charcoal is left which still retains the form of the piece of wood it originally composed. This experiment serves also to shew that the ligneous substance contains the greatest quantity of carbon of any vegetable substance; and that it is therefore well fitted for the formation of substances, so abundant in carbon, as is coal, and every species of bitumen. Even the concurrent influence of air and water effects scarcely any change on it; and it is said to resist, so absolutely, every known kind of fermentation, as to be supposed to be indestructible, except by insects. Reasoning, then, on the chemical nature of this substance, we are led, by analogy, to conclude, that, as in every other case, so here, nature has appointed some agent, by which this apparently refractory substance shall be made to pass into new combinations. Such an agent, the bituminous fermentation appears to be; and every observation warrants the conclusion, that it is the ligneous part of vegetables which is the chief substance susceptible of this peculiar change.

Yours, &c.

LETTER XXII.

OF THE ORIGIN OF THE PURER BITUMENS....NAPHTHA....PETROLEUM....MINERAL TAR....MINERAL PITCH....ASPHALTUM....AMBER....MELLITE....JET AND CANNEL COAL.

THAT the purer bitumens have had the same origin as peat—that they have been produced from the same species of matter, and by the same natural process—and that they differ from it only in having been separated by percolation from the grosser parts—seems to be proved, by the frequency with which they are found together, but more particularly, by the exact agreement observable in their chemical properties. In perfect agreement with peat, as well as with, as we have just remarked, the products of the vinous fermentation, the purer bitumens are composed of hydrogen, carbon, and oxygen; but, as might have been expected from the circumstances under which their formation has taken place, no escape of the volatile principles having been admitted, the new compound appears to be the result of a high degree of concentration of these principles. The great degree of inflammability, possessed by all the bitumens, manifests the large quantity of hydrogen which they contain; and the blackening of the clear and colourless naphtha, on exposure to the air and light, shews the hydrogen to be saturated with carbon and oxygen; since, on the destruction of the equilibrium, by the escape of a portion of the hydrogen, or by the attraction of an additional portion of oxygen from the air, the carbon and oxygen unite, and form the black oxide of carbon or charcoal, by which the fluid becomes gradually darkened: and, suffering a proportionate degree of inspissation at the same time, it acquires the degree of consistence, as well as the colour, by which petroleum is characterised. It is easy to conceive, if the principle itself be admitted, on which I have stated the change of NAPHTHA into PETROLEUM depends, that by its extension we may be enabled also to account for the gradual darkening and inspissation of PETROLEUM into MINERAL TAR; this into MINERAL PITCH, or MALTHA; and this again into ASPHALTUM.

Thus may the formation of the dark-coloured indurated bitumens proceed; but indurated bitumens are of different colours, from jet to light straw-coloured amber: to account for the variety in colour and transparency of the bitumens must therefore be attempted. The colouring of naphtha, as has been just observed, depends on an increase of the relative proportion of carbon and oxygen, manifested by the deposition of the oxide of carbon or charcoal; the inspissation of the fluid going on at the same time. But the deposition of the charcoal may take place in various degrees, according to the circumstances, under which the inspissation takes place. Thus, on the one hand, whilst the naphtha retains its primitive subterranean situation, it may come in contact with the sulphuric acid, which would readily yield its oxygen to the carbon, and at once give it darkness of colour; but, on the other hand, in a situation where no excess of oxygen is present, the more fluid parts of the bitumen may gradually exhale, without its undergoing any decomposition, or alteration, in the original proportion of its principles; and thus may the lighter coloured and harder bitumen be produced.

I cannot quit this subject, without pointing out the great obligations which the lovers of chemistry owe to Mr. Hatchett, for his ingenious observations on the nature of bitumens, and of the changes which they undergo. The opinion which I have above adopted, respecting the deposition of carbon, and the consequent disposition to blackness, in petroleum, asphaltum, &c. originated with that gentleman, and is thus most concisely and happily expressed by him. "The progressive changes of naphtha into petroleum, mineral tar, mineral pitch, and asphaltum, appear to be caused by the gradual dissipation of part of the hydrogen of the bitumen, and the consequent developement or disengagement of carbon. Hence, I am inclined to believe, arise the changes of colour, the degrees of inspissation, and the increased proportion of carbon, found in those substances by chemical analysis. I would be understood, however, to mean that the carbon is only relatively increased, in respect to the other ingredients, in a given quantity of these bitumens, and that it predominates in proportion to the dissipation of a certain portion of the hydrogen, which was originally necessary to the forming of the bitumen in conjunction with the carbon*."

The origin of AMBER, the next bituminous substance which demands our attention, is an enigma, the solution of which appears to be fraught with considerable difficulties. The analysis of this substance, as has been already seen, manifests plainly that it possesses, in every respect, the chemical properties of bitumen. Amber, exposed to the fire, liquefies if the heat be strong; softening and bubbling, without running into drops; which circumstance distinguishes it from the resins. When inflamed, it diffuses a thick smoke, with a pungent odour. Its flame is yellow, but variegated with blue and green. It leaves, after combustion, a black shining coal, which yields by incineration a very small quantity of earth, mixed with a very slight proportion of iron. From these properties we should therefore be led, without the least hesitation, to seek for its formation in the subterranean laboratory of nature; but for its bearing accidental, but unequivocal marks, of having existed, during some of the stages of the process, by which it has been formed, either actually on, or very near to, the surface of the earth.

Naturalists have by no means agreed in their opinions respecting the origin of this substance. Theophrastus speaks of amber as a stone, dug out of the earth in Liguria, and which possesses a power of attraction. Sir John Hill, in his notes on this passage, gives it as his opinion that it is, as he says the best of the modern writers seem certain of its being, a mere native fossil†. Dioscorides thought it to be an exudation from the black poplar. Pliny, who particularly noticed this substance, supposed it to have run from the trunks of trees, resembling pines, in the same manner as rosin is known to flow from the pines, and gum from the cherry-trees; and hence he imagined that are sometimes six feet in diameter, and inhabit the old pine forests; which forests, or at least the spots where they have been, are, he says, the places where the amber is chiefly found. His conjecture is founded on a substance having been found in the nests of these insects, of the consistence of honey, or of half melted wax; having the yellow colour of common amber, yielding the same products by chemical analysis, and acquiring the same degree of hardness by remaining some time in a solution of common salt. It appears, from his observations, therefore, that we should consider amber as a vegetable oil, rendered concrete by the acid of the ants; since wax, according to the experiments of La Metherie, is vegetable oil hardened by the acid of the bee.

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* Philosophical Journal, vol. ii. p. 203.

† Theophrastus on Stones, translated by John Hill, M. D. p. 133.

But the circumstance, perhaps, which adduces the most powerful arguments against this substance being of animal origin, and also against its being intirely of a vegetable nature, is its being found in such large quantities at a considerable depth in the earth. From the account of Junker, which was afterwards copied by Neuman; and from that which is delivered by Hoffman, we learn that the king of Prussia gave orders that search should be made for the subterranean beds of this substance. Directed, most probably, by those marks which point out a spot particularly rich in bitumen, and which are very frequently observable in that part of the world, the required examination was commenced. After getting through the ordinary superficial stratum, they found a bed of sand, beneath which was a stratum of clay. On digging through this, a stratum appeared, which seemed to be formed of wood, very old and decayed, but which very readily took fire. This stratum of bituminous wood they generally found immediately over a stratum of pyrites, which yielded sulphate of iron very copiously; immediately below this was found a stratum of sand, the real matrix of the amber, in which this bitumen was most plentifully found, scattered in small pieces, and sometimes even accumulated in heaps.

Hoffman supposes the amber here to have been formed by the oil of the wood flowing from subterranean heat, like the oil of petroleum, and passing through the bed of pyrites, which lay underneath, thus becoming impregnated with the acid of the vitriol, and thereby obtaining its peculiar nature and appearance.

The opinion of Neuman very nearly agreed with that of Hoffman, he supposing the amber to be formed by the combination of the oil of petroleum with a fine earth held in solution by the acid of vitriol.

The frequent existence of small insects, and of vegetable matters, in the midst of its masses, presents a considerable difficulty to those who consider it entirely as a mineral production. Breynius, however, in the paper already mentioned, remarks that the presence of these foreign matters is not inconsistent with the idea of its subterranean formation; he observing that many insects penetrate beneath the surface of the earth, to deposit their eggs, to change their skin, or to relinquish life; and that vegetable matters are also carried beneath the surface by various insects, who thus retire into the earth. But when it is considered that insects make their way but a little depth below the surface, and that the amber is found at considerable depths, there seems but very little probability that these substances had become imprisoned in this way. Besides, the substance which appears to be the most common matrix of amber, is bituminous wood, and very unlikely to be thus visited, it being a circumstance deserving of notice, not only in reference to this particular circumstance, but as an important general fact, that bituminous impregnations are so unfriendly to animal life, that no living creature has ever been found in peat, or in any other stratum of the bituminous kind.

This particular circumstance has been remarked by several of the most intelligent writers on the history of these substances. Nor do I know of any contradiction to their observation, except in a solitary and very anomalous circumstance related by Lord Cromartie, in the Philosophical Transactions*. By his lordship's account we learn, that in a moss near the town of Eglin in Murray, though there is no river or water which communicates with the moss, yet for three or four feet of depth in the moss there are little shell-fish, resembling oysters, with living fish in them, in great quantities, though no such fish are found in the adjacent rivers, nor even in the water-pits in the moss, but only in the solid substance of the moss. Dr. Darwin considers this as a curious fact, which not only accounts for the shells which are sometimes found on the surface of coals, and in the clay above them, but also for the thin stratum of shells which sometimes exists over iron ore.

The presence of light vegetable matters, and of small insects, such as flies, certainly, at the first thought, appears to yield indisputable evidence of the truth of that opinion which supposes amber to have originally been the gum or resin of a tree; and which, whilst adhering to the tree, had thus caught these substances, which a continued effusion of the same matter had thus involved. But supposing this to have been the case, and that this substance had become buried in the earth, still its bituminous nature remains to be accounted for. It once indeed appeared to me as far from impossible, that the vegetable gums or resins inclosed in the mass of vegetable matters passing into the state of bitumen, might with them be pervaded by the fermentative influence; and, as actually happens with other vegetable matters, lose little if any of their original form and appearance. But maturer consideration has shewn, that the opinion of the learned annotator on the works of Pliny is that which best accords with all those phenomena, which appear so contradictory, if regarded in any other point of view.

The opinion of Mr. Dalechamp, as we have already seen, is, that amber is a bituminous substance, which, exuding in a soft and nearly fluid state, from clefts in the earth where bituminous strata exist, has, during its soft and tenacious state, inviscated and enveloped these different extraneous bodies. Against this opinion there does not exist any objection, since it is not at all difficult to conceive that amber may be the solid form which the transparent fluid naphtha assumes from inspissation under certain circumstances, as asphaltum may be considered to be the result of a similar change effected on petroleum.

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* Philosophical Transactions, N° 330.

It is true that I have considered it as probable that petroleum, an opaque and dark-coloured substance, is naphtha changed by having suffered a degree of inspissation; it may therefore appear contradictory to suppose a transparent substance like amber to be likewise the result of the inspissation of naphtha. But, as has been already remarked with respect to the probable change of naphtha into petroleum, the change is not effected merely by inspissation, but by a separation and a change in the proportion of the constituent principles, hydrogen having escaped and charcoal having been deposited. But most certainly there is nothing to contradict the supposition that naphtha is also susceptible of a simple evaporation, and consequent inspissation, similar to that which the fixed oils undergo, in consequence of the long-continued application of a gentle heat.

If amber were gum or resin which has undergone the change of bituminization, the matters which it contains should certainly also have suffered a similar change. In the few pieces in my own possession, as well as in all others which I have seen, except in one instance, which I shall presently notice, the insects appear not to have suffered the least change, even in their colours, which surely must have taken place, had they been macerating in the softened mass which contains them, during the change it has undergone;

although by the difference of their nature they might be entirely exempt from the other effects of the bituminizating process.

In one specimen, which I possess, containing vegetable matters, the little fragments of moss, and the other particles which are so small as not to furnish the means of judging to what plants, or even to what parts of plants, they belong, do not appear to have suffered the least change, nor to have made the least approach to transparency, excepting one or two pieces, in which it may be readily accounted for, by their extreme thinness and natural proneness to pellucidness, they appearing, when examined by the aid of a lens, very much to resemble in their structure a piece of straw. Not having suffered that change, which this hypothesis supposes the containing mass to have undergone, it seems fair to conclude, that these matters must have been introduced after this particular process had been accomplished in the amber itself, and are therefore preserved, like the insects, in the same state as when first entombed.

Let us not refuse instruction whenever it is offered to us, and especially when, by duly attending to it, we may escape the suspended lash, necessarily held in readiness to check the prompt and presumptive theorist. The specimen of amber to which I have alluded, besides substances decidedly vegetable, and others too equivocal to determine whether they are parts of vegetables or of insects, contains two flies. One of these appears to be in as perfect a state of preservation as when living; the legs being collected nearly in a point, and stretched to their length, as though the flowing bitumen had secured the imprisonment of the little captive, during its active exertions to raise himself from the treacherous surface. The other, on the contrary, appears to have lost its natural colours, and possesses very nearly the transparency, which is very considerable, of the amber itself; as if it had undergone a similar change with the substance which contains it. If it had been a leaf instead of a fly, what would have become of our proposed hypothesis?—But might it not have been only the thin and wasted remains of a dead fly, the transparency of which has been increased by its becoming filled by the bright and clear bitumen?

Having hazarded the conjecture that amber has existed, as a bitumen in a fluid state, and that the foreign substances it contains were introduced in it whilst it was in that state, it may be expected that some instances should be adduced of its having been found in an intermediate state between that of fluidity and that in which it is supposed constantly to exist.

But it must be considered that the characteristic physical properties of amber, such as yielding a peculiar odour, and becoming attractive by friction, depend on its indurated state, and must therefore be sought for in vain, in an inferior state of inspissation. To ascertain, with precision, therefore, from what species of liquid bitumen it is derived, may be impossible; since we are reduced, whilst seeking for the analogous fluid bitumen, to trace it by the aid only of such physical properties as colour, degree of transparency, &c. which are common to both states. By these marks, perhaps, if the substances had been examined with a view to that inquiry, some analogy might have been discovered between amber and those bituminous masses found by Stelluto, and those said to resemble mastich and frankincense, which are described by Dr. Woodward and Mons. Fontaine, and which were found even incorporated with fossil wood, with which substance, we have already seen, amber is found generally associated. Were such specimens again to be found, it would be, certainly, highly desirable to ascertain whether, by continued exposure to a slightly increased degree of temperature, or by long keeping, it would acquire the hardness and other properties of amber.

A specimen of bitumen from Castleton, in Derbyshire, which I possess through the kindness of Mr. Mawes, shews that bitumen, in a soft state, may possess the colour as well as the transparency of amber. It exists in a piece of lime-stone, to which it adheres very closely. Its transparency is almost that of the clearest amber, and the colour, which is most generally diffused through it, is of a deepish yellow, just such as would be conceived from the term amber-yellow, being tinged also in different parts with a brownish red. Its degree of softness is such, that it yields to the slightest pressure, recovering itself, however, on the removal of the pressure, with such a degree of elasticity, as undoubtedly authorizes the placing it among the elastic bitumens.

The elastic bitumens, as we learn by the observations of Mr. Hatchett, may, by being melted, be deprived of their elasticity, and thus might the specimen here alluded to be reduced to the more common state of bitumens; and probably, by a well-managed inspissation, might be made to assume a solid form, without its transparency or colour being at all thereby impaired. In this state, it would undoubtedly become attractive by friction; which property, taken in conjunction with its colour and transparency, would necessarily render its resemblance to amber very close.

By what has been here said, I do not, however, by any means, intend to imply that such a substance would be actually amber; since, perhaps, the formation of amber may depend on peculiar circumstances attendant on its inspissation; and most particularly on some peculiar modification of the oxygen contained in the bitumen from which it may proceed.

Within these few years a substance has been found among the bituminous wood of Thuringia, which has been named, from its colour, HONEY-STONE *(honigstein)* by Mr. Werner, and MELLITE by other naturalists. It is of rather a dark honey colour, and, from its resembling amber also in colour, it has been thought to be that substance in another form. It is usually crystallized in small octahedra, the angles of which are frequently truncated, and sometimes curvilinearly. Sometimes its crystals are dodecahedral, and approaching to the rhomboidal. Its hardness is such as yields easily to the knife, its transparency considerable, its fracture conchoidal, and its specific gravity 1.666. Like amber, its crystals become electric by friction, but not unless previously insulated. It is insoluble in water, and therefore communicates no taste to it. Being heated in a retort, it is decomposed, and yields a bituminous and empyreumatic water, carbonic acid, and a concrete volatile salt; a carbonaceous residuum being left. When placed on burning charcoal, or in a heated crucible, it burns like combustible vegetable matter; leaving a greyish white matter, which has all the characters of alumine, mixed with a small portion of lime. This substance, therefore, appears to be composed of alumine, bitumen, a small portion of lime, and a peculiar acid, which resembles in many of its properties the oxalic acid, but differs from it materially in others. This acid is decomposed very speedily by heat, evaporating in a dense smoke; and by distillation yields a considerable quantity of carbonic acid. When the constituent parts of this substance are considered, with the situation in which it is found, and the substances with which it is associated, there can be but little hesitation in admitting it to be produced by the subterranean decomposition of vegetable matter, and therefore to belong to that class of natural productions of which we are here treating. The appearance which this substance presents may be pretty correctly known by reference to the representation of it, Plate I. Fig. 2.

The bituminous nature of JET is indisputable, it being plainly evinced both by its chemical and physical properties. Indeed it often manifests so exact a resemblance, in every respect, except in its colour, to amber, as to have occasioned it to be named, as has been already remarked, black amber. The blackness which distinguishes it has never yet been satisfactorily accounted for, and indeed offers to our consideration a question difficult of solution.

The learned Wallerius and the celebrated Fourcroy have contented themselves with considering jet merely as indurated asphaltum; whilst others have been satisfied with describing it, with coal, as bitumen, altered by exposure to the action of certain mineral acids. Mr. Hatchett, indeed, in that most valuable paper to which I have already referred, is much more explicit in his account of this substance, and, indeed, makes the only near approach towards explaining the cause of its blackness. I am inclined, he says, to believe, that it is neither asphaltum nor coal, but an intermediate substance, which may be regarded as the first gradation from the simple bitumen into those which are compound.. The matter of asphaltum undoubtedly enters into it in a large proportion, and has consequently stamped several of its characters upon it; but the increase of carbon, and of the extraneous or earthy matter which is intimately mixed, or rather combined with it, has had so much influence, that the characters of coal are also in some measure apparent, and are rendered the more striking by the similarity of certain local circumstances which attend these two substances*.

Whilst endeavouring to account for the darkening of petroleum, I supposed it probable, that the dark matter was formed by the abstraction of a portion of hydrogen, occasioning a proportionate deposition of charcoal, formed by the union of so much carbon and oxygen, as had been thus deserted; and that the colour would vary with the degree to which this process accompanied that of inspissation. By the extension of this principle, I think the blackness of jet may be also accounted for, supposing that, during the inspissation of the bitumen, circumstances the most favourable to the formation, and the separation of the charcoal, must have occurred. The bitumen might have existed in the neighbourhood of substances possessing a high degree of attraction for hydrogen;

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* Philosophical Journal, vol. ii. p. 204.

whilst the sulphuric acid, so frequent in the bowels of the earth, might be ready to yield an additional dose of oxygen. It is in confirmation of this opinion that we learn, from the accounts of almost every one who has described the subterranean situations in which this substance has been found, that it is accompanied by pyrites; a combination of sulphur with metal, each of these substances existing in such a state of purity, as to evince a complete abstraction of any portion of oxygen, with which they might have been combined. Might not the grand agent of this important change have been a metallic solution in the sulphuric acid? In consequence of this being blended with the bitumen, decomposition of both substances must ensue: the oxygen of the sulphuric acid would combine with the carbon contained in the bitumen, forming the charcoal, or oxide of carbon, from which it derives its colour; whilst the sulphur, deserted by the oxygen, enters into union with the metal, which has also, in the same manner, suffered a complete deprivation of its oxygen.

Jet, then, I conclude to be a bituminous substance, containing a considerable proportion of the black oxide of carbon, or charcoal: its levity, its conchoidal fracture, and its glassy lustre, existing in proportion to its freedom from any extraneous intermixture, and to the quantity of unchanged bitumen it still retains.

That jet is a pure bitumen, differing from amber, only in its having undergone some process by which its colour has been changed, will appear still more probable from the following relation of the learned Dalecamp, in his annotations on the Natural History of Pliny*. "I have," he says, "a piece of jet, which, beyond all doubt, has been digested for many ages in the bowels of the earth. It was dug out of the quarries near Narbonne: one half of it is black, and the other yellow, resembling amber."

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* C. Plinii Secundi Historiæ Mundi, lib. xxxvii. Coloniæ Allobrogum, 1615. lib. xxxvii. p. 733.

Having ventured to assume that jet is bitumen changed by a particular process; it may be expected, that as bitumen appears in different forms, so should jet:—and this is the case. According to the form of the substance from which the bitumen derived its origin, will, frequently, be the form in which the jet appears. If the jet has proceeded from a piece of detached bitumen, which had attained a state of softness approaching even to fluidity, such as that in which amber must, at one period, have existed; its surface, and the whole of its external form, will yield an appearance plainly declaratory of the very soft state in which it has existed.

But should it have originally been wood, which during its bituminization had made but little approach to liquefaction, the fibrous texture of the wood may perhaps be still discernible. This indeed frequently happens; and sometimes the external part will display, not merely the texture, but the general form, and even the colour, of wood. A specimen of this kind is depicted, Plate I. Fig. 4. On the flat surface of this specimen the fibrous texture of the wood appears exceedingly well marked; whilst, at the end, the conchoidal fracture, the jet black, and the glassy lustre, sufficiently evince its bituminous nature.

Jet has obtained a distinction, among collectors, into English or foreign; they being guided, in making this distinction, merely by its weight. Thus that which swims on water they describe as English, but that which is heavier they suppose to be foreign. The grounds of this distinction are, that the pieces of jet found on the English shores are thus light, whilst the handsomer specimens brought from France and Prussia are more ponderous: the fact, however, is, that the pieces of jet found on our shores are also foreign; and, having been detached from the strata of the opposite shores, have, in consequence of their lightness, floated here on the waves of the sea.

The transition of jet into CANNEL COAL is frequently very difficult of detection; the difference between the two substances seeming to depend entirely on the quantity of foreign *earthy* matters which have been introduced into the fluid bitumen. When these are absent, or exist in but very small quantities, the bituminous mass very readily manifests electric properties, and its levity is such as to allow it to swim on water: in this state the term jet appears to be most applicable to it. But when the specific gravity of the mass is considerable, and it does not readily become attractive by friction, it may be suspected to contain a large portion of extraneous matters, and will more properly be termed CANNEL COAL.

Another mark of distinction between jet and cannel coal, is one which perfectly accords with the opinion which I have offered respecting their formation. Jet, which is pure bituminized vegetable matter, sometimes, as has been already remarked, displays not only the general form, but the texture and colour, of wood, manifesting that it is purely bituminized wood, some parts of which, and these generally the cortical, having resisted the influence of the fermentation more than that part which is more generally considered as wood. But in cannel coal, which has been in so fluid a state as to have admitted the intermixture of earthy matters, seldom any thing of this kind appears. Impressions of various vegetable substances are indeed often displayed on its surface, possessing such a degree of correctness and sharpness, as plainly to evince its having been in a very soft state when the impressing substance was applied to it; but these extend no deeper than the surface, its substance or texture seldom pointing out the substance from which it originated. Representations of the appearances which thus offer themselves to our view you will see depicted, Plate I. Fig. 6 & 7.

Yours, &c.

LETTER XXIII.

OPINIONS RESPECTING THE FORMATION OF COAL....EARTH IMPREGNATED WITH PETROLEUM, THE OPINION OF BUFFON AND GENSANNE....OPINION OF SIGN. ARDUINO....OF DR. HUTTON AND PROFESSOR PLAYFAIR....OF MR. WILLIAMS....OF MONS. TINGRY....OF DR. DARWIN....OF MR. KIRWAN....OF MR. HATCHETT....OF MONS. PATRIN....OF MONS. FOURCROY.

AMONG the humiliating proofs of our limited powers of inquiry, there are few which are more striking, than that which is manifested by the inefficiency of our investigations relative to coal. Respecting the origin of this substance, so plentifully bestowed on us for our daily use; and consequently continually subjected to the immediate examination of our senses, the most widely different opinions have been held; and by those, too, who have been the most competent to form a proper judgment. Even with that theory which has been the latest promulgated, by a gentleman whose extraordinary knowledge in mineralogy and chemistry stamps a high degree of authority on every opinion he adopts, I am under the necessity of expressing my dissatisfaction.

This circumstance is the more unpleasant, since the observations which led to the objections to this ingenious theory, have also led to the adoption of an hypothesis, which, although sufficiently seductive to hold my judgment captive, may be found, by the more discerning, to possess much less probability than those opinions to which it is opposed. To enable you to form a judgment on this subject, I shall proceed to place before you those opinions which have been most generally adopted, and such objections as seem to affect their validity.

The specific gravity and hardness of some species of coal, have procured coal in general to be distinguished, by some, by the term of *stone-coal.* Struck by the predominance of these qualities, and perceiving also the great quantity of bituminous matter contained in coal, this substance has been considered, by some chemists of considerable knowledge and abilities, as being an earth, or rather a stone of the argillaceous genus, which has become impregnated with petroleum. The impropriety of thus considering it must, however, at once appear, when it is recollected, that chemical examination has shewn, that, in common coal, the proportion of earth, to that of carbonaceous and bituminous matters, is so very trifling, as seldom to exceed a thirtieth part of the mass.

In some instances, indeed, such as the slaty cannel coal, from Ayrshire, in Scotland, analysed by Mr. Kirwan, and the stony coal of Macinaia, the analysis of which has been given by Signor Fabroni, the earthy parts have amounted to a fifth, and even one half of the whole mass. But these are substances which deviate so much from the characters of coal, as not to be admissible into the same class with it, but should be rather considered as varieties of slate, lime-stone, &c.

Others have been of opinion, that coal is entirely of marine origin; and formed by the fat, and various unctuous matters, which have proceeded from the innumerable tribes of animals which have peopled the ocean. This mass of matter is supposed to have accumulated, and at last to have become covered by various strata, in consequence of the different changes which the surface of the earth, and the receptacles of the waters of this globe, have experienced. To shew the improbability of this hypothesis, it is, perhaps, sufficient to remark, that the levity of such substances could never admit of their accumulation at the bottom of the sea, which, according to the principles of this theory, must be supposed taken place.

Dr. Hutton ingeniously laboured to establish his hypothesis of the succession of worlds by a system of revolutions, occurring at regular periods, each successive period of existence being, according to our measurement of time, of indefinite duration; leaving us no vestige of a beginning,—nor prospect of an end. Agreeable to this hypothesis, the Doctor imagined that coal is formed by the slow deposition of oily and bituminous matters at the bottom of the sea. These bituminous and oily matters he supposes to have originated in the dissolution of the various animal and vegetable bodies, which are continually perishing on the surface of the earth, and in the waters of the ocean. The fuliginous matter which is separated during the combustion of various bodies on the surface of the earth, he supposed is washed off the surfaces on which it falls, by the rain, and, being thus made to flow into the rivers, is carried by them into the sea; where it also adds, by its deposition, to the mass which is accumulating at its bottom. Another source from which he supposes this matter to be derived, is the moss-water, or the water which drains from peat-mosses. This moss-water, the Doctor says, leaves, upon evaporation, a bituminous substance, which very much resembles fossil coal; and, as the continued action of the sun and atmosphere upon this oily substance tends, by inspissation, to make it more and more dense or bituminous, he, therefore, sees no difficulty in supposing a continual separation of this bituminous matter, or inspissated oil, from the water; and a precipitation of it to the bottom of the sea, along with the subtle earthy particles which the water also contains. These he supposed to subside together in an uniform manner, producing a stratified mass, which, becoming covered by an immense weight of superincumbent earth, must have been thereby exceedingly compressed and condensed, and finally consolidated, by the powerful influence of subterranean heat.

Waving, as foreign to the immediate object of our inquiry, any observations on Dr. Hutton's general geological system, I shall only here remark, that his particular theory, respecting the formation of coal, is exposed to the same insuperable objection, as was offered against the hypothesis just noticed, that of making substances of much less specific gravity than water, sink through that fluid. Can any intermixture with impalpable earthy matters, which the Doctor supposes to take place during their subsidence, possibly authorize the supposition that light bituminous, or fuliginous matters, or vegetable or animal oils, could subside through the waters of the ocean, so as to form this extraordinary subaqueous stratum of fossil coal?

The opinions of Dr. Hutton have been combated by several ingenious writers; but those which respect the origin of coal have been attacked by no one more successfully than by Mr. Williams, in his History of the Mineral Kingdom. This gentleman, possessing a very considerable degree of knowledge on this subject, the result of actual observation, and confining himself to those inferences which seemed necessarily to flow from the phenomena which he remarked, concluded that the antediluvian timber was the original of our present coal. This conclusion he was led to make, from having observed the form, grain, and texture of timber so frequently in coal. He observes, that wood is the origin of coal is so plain and evident a truth, that we can almost trace and point out the particular species of wood which composed particular species of coal*. He more particularly delivers his opinion in another place, where he says, "I am of opinion that the antediluvian timber floated upon the chaos, or waters of the deluge, until the strata of the highest mountains were formed, with much of the other strata in our sight; and that during the height of the deluge, and the time in which the greatest part of the strata were forming, the timber was preparing, and fitted, for being deposited in strata of coal; and that the coals, with their concomitant strata, were among the last that were formed. But how, and by what means, every thing in this great work was fitted, and carried on, belongs to higher wisdom and intelligence than mine to explain*."

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* History of the Mineral Kingdom, vol. i. p. 251.

I will beg leave, Mr. Williams says†, "to propose another probable source of coal. I believe, I may call it a real one, and that is the antediluvian peat-bog." The grounds on which Mr. Williams formed this opinion were, the having seen coals, which seemed to bear a very strong resemblance to peat; and, on the other hand, peat, which, on being dried, became nearly as black, and as hard as coal. The particular reasons Mr. Williams employs for this latter opinion, I shall at present defer, since they will appear when I shall offer my own conjectures on this subject. Petroleum, Mr. Williams is, however, convinced, is not at all concerned in the formation of coal; although he acknowledges that some species of petroleum may have a near relation to coal.

It is right to apprise you, that not only has the conversion of petroleum into coal been thus strenuously opposed, but that the derivation of petroleum itself from vegetable matter is also denied. The learned Wallerius strongly objects against such an origin; grounding his objections chiefly on it differing so much in its sensible, as well as chemical qualities, from vegetable matter. He is the more confirmed in his opinion, from the petroleum being found inclosed in mountains, and in subterranean cavities, where no traces of decayed vegetables are to be seen, and from the result of its analysis being so very different from any vegetable matter. Considering also, that there is no reason to suppose that nature is less disposed to form an oil in the mineral kingdom, than in any of the others, he concludes that *naphtha* is generated from a most subtile inflammable mineral matter, combined with water by the medium of an acid. *Petroleum* he supposed to be formed by the addition of a calcareous earth to the naphtha, dissolved and retained by its acid part. From the farther combination with earth he supposed that *maltha* was produced; and by the exsiccation of this, asphaltum.

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* History of the Mineral Kingdom, vol. ii. p. 212. † Id. vol. ii. p. 194.

Monsieur Tingry, in his observations on some extraneous fossils of Switzerland*, considers the *detritus* of organised bodies, buried in the earth, to be the true matrix of the different liquid and solid bitumens; believing that these organized bodies are made to assume those characters which distinguish them, more or less, from the substances from which they originated, by the *influence alone of mineral vapours*†. He supposes the different states of hardness, tenacity, or fluidity, which characterise coals, maltha, petroleum, &c. to be entirely the consequence of spontaneous decompositions, and new combinations, effected by *mineral vapours*, and particularly by a certain quantity of water. These substances he supposes to thus undergo, during the revolution of ages, and in the silence of nature, an analysis similar to that which takes place in closed vessels: becoming heated in consequence of their slow decompositions, and new combinations; and thus being resolved into charcoaly, which frequently manifests the entire form, or at least the characteristic marks, of organized bodies‡. This operation he supposes is, beyond doubt, accelerated by the presence of certain mines of iron; since he observes that Derbyshire furnishes a mixture of iron and manganese, which takes fire spontaneously on being moistened with linseed oil. Subterranean fires, he therefore conjectures, may be produced by the mixture of oil of petroleum, with a similar ore of iron with that just mentioned.

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* Transactions of the Linnæan Society, vol. i. p. 57. † Id. p. 59. ‡ Id. p. 60.

It is reasonable to conjecture, he thinks, that the remains of vegetables, accumulated in large heaps, and exposed to the effects of those particular combinations which occasion the heat of certain mineral waters, or to the influence of volcanic fires, may have undergone a real distillation; and that the substances thus formed, meeting with water which impeded their farther decomposition, have been carried to the surface of the earth, and appear there under the form of naphtha, &c. Under other circumstances, he conceives, that these same oils, thus detached by distillation from the wood, have filtered insensibly into the beds of sand and clay, and thus have produced the formation of coal and bituminous schisti; whilst, under other circumstances, these oils, accumulated in the interior cavities of the earth, have assumed the consistence which we observe in mineral pitch.

To the opinion of Mons. Tingry, respecting the gradual decomposition of vegetable matter, I certainly cannot object; but later observations, and particularly those of Mr. Hatchett, have clearly demonstrated, that, however difficult it may be to account for the different states, in which the bitumens are found to exist, the action of subterraneous fires, and the operation of distillation, cannot have been the agents which have occasioned those varieties, in the forms under which these substances appear to us. It may be proper to remark, with respect to this supposed influence of subterranean fires, that Dr. Hutton, and many of the French chemists, have adopted the same idea, and to as considerable an extent.

Dr. Darwin was of opinion, that morasses seem to have undergone a fermentation; but that the formation of coal depends on a distillation similar to that which is supposed by Dr. Hutton. The Doctor says, that "woods in uncultivated countries have grown and fallen through many ages, whence morasses of immense extent;" or, as he beauifully expresses it, in his charming poem, those of the same denomination now contain, since their disintegration took place at so early a period."

On this supposition, Mr. Kirwan proceeds to say, "I think the formation of coal-mines, and most of the circumstances attending them, may naturally be accounted for.

"And, first, as to the seams of coal themselves, and their attendant strata; they must have resulted from the equable diffusion of the disintegrated particles of the primitive mountains, successively carried down by the gentle trickling of the numerous rills that flowed from those mountains, and in many cases more widely diffused by more copious streams. By this decomposition, the felspar and hornblend were converted into clay; the bituminous particles, thus set free, reunited, and were absorbed, partly by the argil, but chiefly by the carbonaceous matter with which they have evidently the greatest affinity; since they are separable by boiling water from the former, and scarcely, by the strongest heat in close vessels, from the latter; and even in an open fire, only by a heat much superior to that of boiling water. The carbonic and bituminous particles, thus united, being difficultly miscible with water, and specifically heavier, sunk through the moist, pulpy, incoherent, argillaceous masses, and formed the lowest stratum, unless in cases where their proportion to the argillaceous particles was so small, that the latter had subsided and coalesced, before the former could have been reunited; in that case the clayey particles formed the lower stratum of indurated clay. But if the petrol were in the greatest proportion, it frequently sunk first, in the form of a soft bitumen, carrying with it the clay, and forming beds of shale, or bituminous shale, according to its proportion. By oxygenation it becomes specifically heavier than water*."

To attempt to overthrow opinions erected on so broad a basis, as the vast portion of chemical and mineralogical knowledge which

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* Geological Essays, p. 330

Mr. Kirwan possesses, cannot but, at first sight, appear to be an act too presumptive to promise the least success. But when even the most wise and intelligent loosen the reins, and lessen those restraints which their judgment, in general, places on their imagination, he who first notices any unwarrantable deviation from established principles may, without fearing censure for his interference, boldly venture to point it out.

But, indeed, the disposition of the various substances, of which the earth is composed, yields us so little satisfactory information; and the data we thus obtain are so few, and so unconnected, as to render the aid of conjecture indispensably necessary. Hence, on the subject of the formation of this globe, and of the various revolutions it has suffered, the wisest men have formed the most extraordinary and romantic conclusions. Nor can this occasion surprise, when it is considered, that to point out the operations of nature, by which the various substances which constitute the earth obtained their present figure and arrangement, is, in fact, an attempt to form a history of the most remote periods, with the scantiest stock of materials possible. In such a performance, success cannot frequently be expected; it must resemble the bold sketch of a master, who, whilst depicting scenes which have originated in his own rich fancy, strives, but, perhaps, ineffectually, so to correct them by his judgment, as to make them accord exactly with nature. To approach near to the completion of such an undertaking requires a considerable portion of genius, the efforts of which must be directed by a mature and correct judgment; but very inferior abilities indeed may be sufficient to enable any one to point out an instance or two of disagreement between the conjectures which are offered, and the circumstances they are intended to explain. This I shall therefore attempt.

In the hypothesis of Mr. Kirwan, the most obvious difficulty seems to be in admitting the subsidence of so light a substance as bitumen, through the waters of the ocean. In no form, either solid or fluid, do we know of the existence of any pure bituminous matter, or even, when combined with oxygen, which is not of considerable less specific gravity than water; and consequently, as Mr. Kirwan himself observes, of the unctuosity of marine animals, whilst examining the theory of the celebrated Arduino, it should rather float, than sink in the sea. Nor does even the combination of carbonaceous matters with the bitumen remove this difficulty. Mr. Kirwan supposes the carbonaceous as well as the bituminous particles to be separated by the disintegration of the antediluvian mountains; and then to enter into reunion, and suffer a precipitation through the water. Such a combination I have endeavoured to prove is constantly taking place, in every case where the thickening of the substance, and the darkening of the colour, of any bituminous substance is going on. Thus, in consequence of the addition of oxygen to the thin and limpid naphtha, a combination of that principle with the carbon ensues; charcoal or oxide of carbon is formed, and the fluid becomes thicker and darker, assuming the form of petroleum. By a continuance of this process, these effects are produced in a still higher degree, and the hard, dark bitumen, asphaltum, or the still more highly carbonaceous bitumen jet, is formed. But every one of these substances, we perceive, are of such a degree of specific gravity, as, when pure, to be constantly found to swim on water. The possibility, therefore, of substances, of this nature, sinking through the moist, pulpy, incoherent, argillaceous mass, as Mr. Kirwan describes it, certainly does not appear; neither could it possibly be admitted, even if such a subsidence were granted, that such materials should form, as Mr. Kirwan also conjectures, the lowest stratum.

Whilst on this subject, I must make one more observation, which appears to me very forcibly to contradict this supposition of the formation of coal by deposition. The specific gravity of the substances forming the roof of coal, constantly exceeds in a very high degree that of the bituminous mass they cover; they containing very frequently so much metallic matter as to render them exceedingly ponderous. Now the disintegration, of which Mr. Kirwan speaks, he supposes to have been so complete, as to have converted the hard and close-grained hornblend and felspar into clay. By so minute a disintegration, the bituminous particles must have been set free; and must have risen to the surface, with as great a degree of rapidity, as the earthy and metallic particles would have sought the bottom. But, on the supposition of Mr. Kirwan, the bituminous and carbonaceous, the earthy and the metallic particles, being all suspended in the same fluid, a deposition of the oxygenized carbon and bitumen first takes place, and this is succeeded by the descent of the earthy, and of the still more ponderous metallic particles.

It appears equally difficult to conceive the formation of beds of shale, by the subsidence of bitumen. If, says Mr. Kirwan, the petrol were in the greatest proportion, it frequently *sunk first, in the form of a soft bitumen, carrying with it the clay,* and forming beds of shale, or bituminous shale, according to its proportion. Considering this position, with all that care and deference, which a dissent from the opinions of so justly celebrated a chemist ought to excite, I still am unable to discover, how the effects, here described, could possibly result from such a combination of circumstances, as those to which they are thus ascribed.

Mr. Hatchett, whose most valuable observations on the bitumens have very much facilitated our inquiries, into the nature and origin of these substances, is very decidedly of opinion that coal, as well as the other bitumens, are of vegetable origin; although he does not deny the possible intermixture of animal matters. But we shall soon have occasion to advert more fully to these observations, to which the progress of the science of chemistry, as to the knowledge of the nature of these substances, is so much indebted.

Mons. Patrin states, that volcanoes throw up large quantities of bituminous and argillaceous matters; and he derives the origin of coal from this source: supposing that coal, and its interposed beds of stone, have been deposited by the alternate ejection of bitumen, and of earthy matters, from submarine volcanoes. How, he says, can it be supposed, that coal can have been formed from vegetables, when considerable beds exist at the height of twelve thousand feet in the *Cordilieres* of Peru, and at more than six thousand feet in height on the Dauphinese Alps; where, he adds, these beds have been deposited, at a time when vegetables did not yet exist, and when the waters covered the whole surface of the globe. How otherwise, he asks, can we account for the regular alternate beds of coal and layers of stone; such as, for example, are seen in the colliery at Liege, where there are sixty-one beds of coal, alternating with as many layers of stone, of a vast thickness*.

The latest writer of celebrity on this subject is Mons. Fourcroy, who, speaking of the origin of this substance, says, the greater part of naturalists consider coal as the product of the remains of wood, which has been sunk, and afterwards changed by the water, and by the salts of the sea. Coal, he observes, seems to owe its formation to the decomposition of an immense quantity of marine and terrestrial vegetables, and to the separation of their oil, which becomes united to the aluminous and calcareous earth. It cannot be denied, he remarks, that animal matters also enter into its composition, and afterwards observes that a considerable quantity of ammonia is yielded by the distillation of coal, which favours the opinion of its animal origin, since bodies belonging to this class of compound substances always yield ammonia during their distillation†.

* See article HOUILLE, Dictionnaire d'Histoire Naturelle.

† Systeme des Connoissances Chymiques, tom. viii. p. 241 & 244.

Evident indecision is observable in the statement of the foregoing opinion, respecting the formation of coal; doubtlessly arising from Mons. Fourcroy's disposition to countenance the idea of animal bodies having contributed greatly, and perhaps even more than vegetables, to the formation of some kinds of bitumen. Want of that precision, which, in general, marks the observations of this celebrated chemist, is also discoverable in the explanation he offers of this process of nature.

The supposition of the separation of oil from the mass of decomposing vegetables is not sufficiently supported by the facts which manifest themselves, during the resolution of vegetable matters, to allow it to form the basis of a system, intended to explain this mysterious operation. For if such a separation of the vegetable oils were even admitted, could the quantity of a principle which vegetables, in general, possess so sparingly, be considered as sufficient to account for the immense masses in which this substance is known to exist?

Yours, &c.

LETTER XXIV.

ENQUIRY RESPECTING THE ORIGIN OF COAL CONTINUED....HYPOTHESIS PROPOSED....MOSAIC ACCOUNT OF THE DELUGE.... OBJECTIONS AGAINST....UNIVERSALITY OF THE DELUGE.... CHANGES THUS EFFECTED....VEGETABLE MATTER DISPOSED IN SITUATIONS IN WHICH COAL NOW EXISTS.

I HAVE been highly entertained by a letter from our friend Winton, in consequence of your having shewn him my account of the various systems respecting the formation of coal. Indeed his remarks are so just, and his satire so pointed, as to give me some apprehension for the fate of my present letter, when subjected to his criticism and keen raillery. He reminds me of Dr. Halley's conjecture, that the world on which we dwell may have another habitable world within it, to which may be attached a system of subterranean luminaries, resembling those which yield light to our upper world, but necessarily moving within a smaller sphere*. He sarcastically asks, whether our volcanoes are any thing but the grand outlets of the furnaces, and our veins of bitumen any thing more than the clogged-up chimnies of this inner world? The dread of criticism must not, however, deter me—I have engaged myself to the work, and therefore must not shrink.

Having laid before you the several opinions which have been published, respecting the formation of coal, and having found myself under the necessity of stating my suspicion of their insufficiency, to account satisfactorily for the origin of this substance, it becomes a duty to offer any observations, which may seem to be likely, in the least, to elucidate a subject involved in so much mystery. But be assured that, whilst doing this, I am not ignorant of the difficulties which surround me; nor, knowing how considerable these are, do I presumptuously expect to etablish an impregnable system. On the contrary, I fear, that many unforeseen, and powerful objections may arise, against opinions thus hazarded, on a question which has been left in a great measure undecided, after careful discussion, by men of eminent abilities. If, on the one hand, I experience the mortification of differing from opinions which have been generally received; it is, on the other hand, highly satisfactory to know, that this difference is so little, as in some instances, to consist merely in an extension, and in others, in little more than a modification, of those opinions. Thus the explanaof the vegetable system, yield the strongest grounds of belief, that the earth, in its antediluvian state, was most plentifully stocked with plants and trees of every kind and size. The employment which was allotted to Adam, for "the Lord God took the man, and put him into the garden of Eden to dress it and to keep it[*];" and the extensive space which this garden is implied to fill, for "out of the ground (of this garden) made the Lord God to grow *every* tree that is pleasant to the sight, and good for food," as well as the general scenery, and the most prominent circumstances in this history of the first man, all concur to shew, that the mandate of the Creator was, in this respect, completely fulfilled, and that "the earth brought forth grass and herb, yielding seed after its kind, and the tree yielding fruit, whose seed was in itself, after his kind[†]."

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* Miscellanea Curiosa, p. 43.

Agreeable to the same sacred tradition, the earth was peopled from a single pair; and, from various particulars which appear in the history of their immediate descendants, we may perceive, that the arts which they possessed, and the kind of life which they led, accorded with those which the historians of later times have shewn to have been adopted by the aboriginal inhabitants of every country. Their dress was simple; and their employments, that of keeping of cattle, and of tilling the ground, were those of man in his rudest and most uncivilized state.

After a certain period, seven generations from Adam, we are told the arts of civil life began to appear. "Jabal was the father of such as dwell in tents, and of such as have cattle—Jubal was the father of such as handle the harp and organ—and Tubal Cain was the instructor of every artificer in brass and iron[‡]." Whether this relation is to be taken literally, and that these arts were actually invented during the eighth generation of mankind, or whether whom may be mentioned the Right Rev. Bishop of Clogher, have imagined, that the deluge should not be considered as having covered the whole face of the earth. His Lordship was of opinion, that some parts of the then habitable world, which by the force of the deluge were separated into islands, and were divided from the continent whereon the ark landed, were in some sort exempted from the common calamity, brought on the rest of the world by the deluge; inasmuch, his Lordship says, as the continent of America, and many islands in the East Indies, are at present partly inhabited by wild beasts and noxious animals, which it is not reasonable to imagine, that any body could, or would, have imported thither since that time[*].

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[*] Genesis ii. 15. [†] Genesis i. 12. [‡] Genesis v.

To account for this particular circumstance, may not, perhaps, be very easy; but, however, it is not necessary to be done, in proving the prevalence of the deluge over every part of the known world; since testimonies sufficient to this fact, are yielded by those wonderfully preserved remains of former ages, which form the general subject of these inquiries, and which have been discovered in almost every part of the known world. Even the very spots which were thus pointed out, by his Lordship, as having been exempted from the fate of the rest of the world, contain the most astonishing and interesting remains of organized beings; at once proving that the waters of the deluge did cover the whole earth, and leading [illegible] to regard the globe we inhabit as one vast tomb of a former world.

Assuming it then as proved that the deluge did overwhelm the whole of this globe, it next becomes necessary, to inquire what changes were probably thus effected. Very different opinions have been maintained respecting the degree of change which took place on the earth, in consequence of the deluge. Some have supposed that the change was but slight and superficial, affecting the upper may be concluded, were covered with their appropriate tribes of trees and plants. Assuming these for the generalities of the earth's external form, it is evident that the waters, whether supplied by the rain alone, or by other sources, as seems to be implied by the breaking up of the fountains of the great deep, must necessarily have first filled the lower parts of the earth. When it attained a greater height, then must this powerful element have rushed in torrents from valley to valley, breaking down, or surmounting, every intervening obstacle; and laying prostrate the vast forests with which the surface was every where clothed. Of the trees thus overthrown, the lowest stratum of vegetable matter would be formed, which would soon become buried beneath the sediment, which would be continually depositing from the superincumbent waters, loaded with every species of earthy, and even mineral matters, with which they would be impregnated by the effects of an alluviation more powerful than we can possibly conceive.

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[*] Vindication of the Histories of the Old and New Testament, p. 171.

As the volume of the water increased, the sides of the mountains would become subjected to the violence of its action. The roots of the trees, which grew on their sides, would become loosened, and the trees themselves, and the earth in which they had grown, with the various other vegetables which had been generated and nourished in the same matrix, would fall into the flood, and form a fresh strata of vegetable matter. Thus would a mass of vegetable matter, immense beyond conception, become subjected to the domination of this powerful element. These several strata of vegetable matter would become covered by strata of earth formed by the gradual deposition of ponderous, but minutely divided particles, which would soon form a covering so compact, as would be able considerably to resist the ordinary fluctuation of the water. Similar alternating strata, constituted by the successive subsidence of masses of vegetable matter, and of finely divided particles of earth, may be supposed to be thus continually forming until the waters had covered the tops of the high hills. Thus may, perhaps, be explained the situation of distinct veins of coal, separated by stony strata; all, perhaps, the work of deposition.

From what cause it proceeded, it will, perhaps, be impossible ever to determine; but there is certainly reason to believe, that the waters of the deluge possessed a very considerable solvent power over even those earths which we consider as most untractable. From the intermixture and crystallization of these proceeded those siliceous and spathous veins which alternate with and intersect the various strata which form that part of the earth which has been subjected to our examination.

Not only the form, but the substance, of the surface of the newly-formed post-diluvian world must have differed very much from that which existed before the flood: vast and innumerable must have been the changes, which it must have undergone, before the respective situations of the waters, and of the dry land, could have even made an approach to stability. From the violent action of the waters at the period of their first effusion over the earth, as well as during their residence and their departure, the continuity of the earth must have been broken in many places; necks of land must have been left, forming, according to circumstances, isthmuses, or promontories; vast masses of earth, considerably undermined, would remain on the superior parts, and on the declivities of mountains; and, as vegetation would doubtlessly be rapidly renewed, wherever the earth became uncovered from the waters, these projecting parts would soon be covered by the verdure of various vegetables. But the newly-formed surface would, perhaps, for a considerable period, be continually undergoing a change of its form: the waters, urged by violent tempests, and agitated by receiving the immense fragments of falling mountains, might separate those necks of land of which we have just spoken, and which its slower action had been continually reducing: the divulsed parts of which, with the vegetation they bore, would sink in the waters of the ocean. Thus also, by the force of tempestuous winds, and even by the gradual influence of the weather, large projecting and dependent portions of mountains, with their newly-produced forests, would frequently be sinking in the surrounding waters. Thus would additional layers of vegetable, and of earthy matters, be repeatedly formed over those strata of vegetables which had been overthrown by the first violence of the deluge.

As when the greater part of the waters of the deluge had drained off, and when the surface of the globe again became divided into water and dry land, the lower and more excavated parts would necessarily retain the water for a long time; thus, as well as the rivers and seas, would immense lakes be formed. In these lakes would the numerous tribe of aquatic plants flourish, which, as the waters at last subsided, would cover the bottoms of these hollows with a mass of vegetable matter, covered by a deep coat of earthy deposition; which, drying gradually, would secure the subjacent stratum from the action of the air. From the numerous revolutions which the newly-formed earth would be destined for a time to undergo, many of these hollows might be again filled with water. Adjoining lakes might burst through their interposed mounds, and thus refill them; or, among the mountains which helped to form the basons of these lakes, some which had been weakened in their bases, by the previous action of the waters, might now become more effectually undermined, and might fall into the lake beneath, and thus force the water beyond its newly-established limits. In new lakes, thus formed in the cavities of previously existing ones, aquatic vegetation would again go on, whilst a compact stratum from the subsidence of the suspended earth would form at the bottom; and when the waters themselves had drained away, a fresh deposit of vegetable matter would be formed, which would, like the former, become covered with a stratum of mud, capable of acquiring, as in the former instance, a considerable degree of hardness.

Such of the vegetable matters, as might float on the last remaining waters of the deluge, might be washed into other hollows of less depth, and, becoming only covered with a moderately thick coat, would become peat bogs; and, if left for a long series of time totally undisturbed, would, perhaps, form lakes of petroleum, similar to that which now exists in the island of Trinidad, a description of which has been already given in the Fourteenth Letter.

When the different facts are considered, which have been already related, respecting the situation of coal, and of the various strata which are interposed between its several beds; and which have evidently been produced by gradual deposition in water, I trust that no glaring incongruity will appear, in the opinion, that vegetable matter of the antediluvian world might be disposed, by the waters of the deluge, in all those situations in which we now find coal.

Yours, &c.

LETTER XXV.

INQUIRY WHETHER THE VEGETABLE MATTER WAS DEPOSITED AT THE DELUGE UNDER CIRCUMSTANCES FAVOURABLE TO ITS CONVERSION TO COAL....BITUMEN ALONE NOT FITTED FOR FUEL....OTHER MATTERS NECESSARY TO BE ADDED....PECULIAR ARRANGEMENT OF THE PARTICLES.

THE next question which demands consideration is, whether such an arrangement of the materials of the flooded surface of the antediluvian world, as has been assumed in my last Letter, would be likely to promote such chemical changes, in the strata of vegetable matter, as would effect its conversion into coal? This we will therefore now inquire into.

That vegetable substances placed in a mass, in a subterranean situation, will, with the aid of moisture, or, perhaps, with only that which they themselves contain, pass into a peculiar fermentation, and become thereby converted into bitumen, has been already asserted in a former Letter*; to which I must now refer you, for those arguments, which appear to me, to be best calculated to support that opinion. Your attention must here, however, be requested to one additional consideration; which will serve, very probably, to corroborate the application of that hypothesis to the present subject, the origin of coal.

In the promulgation of that hypothesis you perceived, that the circumstance, on which the bituminizating process was supposed essentially to depend, was the seclusion of the vegetable matter, from the atmospheric air. According to the accuracy with which this part of the process was performed, it necessarily follows, would be the approach to a state of perfection, in the product of the operation. Now, by a slight revision of what has been said, in the Letter immediately preceding this, you will not fail to perceive, that whilst endeavouring to ascertain the most probable mode, in which the vegetable matter of the antediluvian world was disposed, there appears great reason to suppose, that the disposition of it must have been such, as would most certainly secure the completion of the assumed process.

Buried in a considerable mass,—thoroughly imbued with water, and covered over with dense, compact strata of earth, its seclusion from the atmospheric air must have been very accurate; and taking it for granted, that the change it was to undergo would much depend on this circumstance, then we have every right to conclude, that its conversion into bitumen would be produced most certainly and effectually.

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* Letter XVIII.

In another Letter*, I have also endeavoured to make it appear, that the darkness of colour of some of the bitumens, from the brown of petroleum to the black of jet, proceeds from the saturation of the carbon, one of the constituent principles of bitumen, with oxygen. On this point, I can be able to add but little to what I have there attempted to establish. To one circumstance only I have to attract your attention, which is, that, during the formation of coal, the bitumen is thoroughly pervaded by other substances, impregnated with ogygen; and from which, by superior power of attraction, the carbon is able to detach it, and then engage it in combination with itself. That this is the case, and that these substances are applied to the bitumen, under circumstances the most favourable to the promotion of such a combination, will, I trust, appear, whilst attempting to ascertain the circumstances on which some of the other physical and chemical properties of coal seem to have chiefly depended.

From what has been already said, whilst speaking of the formation of bitumen, you will have perceived that, I am of opinion that, in proportion as the process of bituminization approaches to perfection, the substance acted upon acquires a state of fluidity. With respect to coal, the formation of which may be regarded as the grand and important end, for which this process has been instituted, it would be reasonable, *à priori*, to conclude, that the laws of nature would decree that the substance which is to undergo this necessary change, should, in general, be so disposed, as to have secured to it the full effect of the operation of every stage of the process. But should the circumstance of coal having existed in a state of fluidity, be supposed to be not fairly inferable from these premises, some increase of the probability of the circumstance may surely be derived from a view of the substance itself. For whether we dwell upon the peculiar fracture of common coal, or on the vegetable impressions which are frequently found on it, the idea of its having existed in a fluid state must present itself to any one, whose mind has not been prepossessed by some contradictory hypothesis.

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* Letter XXII.

From this state of fluidity would result a very necessary change in the nature of the mass. With the vegetable matters which have been supposed to have been sunk in the waters of the deluge, a considerable portion of mud and gross earthy particles must have been blended; these, however, when bituminization had given fluidity to the mass, would, in consequence of their superior gravity, settle, and form that stratum which was to become the floor of the pit, leaving the pure bitumen above.

By reverting to a circumstance mentioned whilst speaking of peat, and of bituminous wood—their eager retention of the water in which they had been immersed, parting with it as difficultly as would a sponge, and that only on the employment of a considerable degree of pressure—we learn, that water may be so thoroughly interspersed between, and so intimately united with, the particles of bitumen, as to constitute a part of its mass. This, however, takes place in the pure bitumens only, whilst in a soft state; since where these substance have once been deprived of the water they contain by exsiccation, they are no longer capable of entering into union with it; becoming impermeable to that fluid with which every part had before been penetrated. Thus, in many other substances, such as the balsams, gum resins, caoutchouc, and vegetable gluten, a certain portion of water enters into their original composition, being a necessary constituent of the substance, whilst existing in that form; but when these substances become dry and hard, water is capable of being united with them but very sparingly, if at all. The Abbé Fortis, whilst describing the mine of pisasphaltum, in the isle of Bua, relates that, upon breaking the drops of bitumen, which having exuded in a soft state, had become hard and brittle, he found in the centre of each a drop of clear water. That water exists formally in petroleum is rendered probable, by its being produced in a considerable quantity by the distillation of this substance. It must indeed be allowed, that, in the operation of distillation, such a new combination of the principles of which the petroleum is composed may take place, as may occasion the formation of water; the hydrogen and oxygen thus uniting, whilst the carbon is left in the residuum contained in the retort: but that water may exist in, and form a part of the original substance, there does not appear to be the least reason to doubt[*].

A circumstance which respects the roof of coal-pits is well deserving your attention, in this place. Generally the schistose covering, which forms the roof, is, for a considerable thickness, so impregnated with bituminous matter as to possess a degree of combustibility, which is, in some instances, so great as to allow the employment of these schisti, for the purpose of combustion, in the burning of lime, smelting of metals, &c. A similar impregnation of the earth which covers the fossil wood of Munden, described by Professor Hollman, and of that of Bovey, described by Dr. Milles, is also observable. Impregnation of the earth to a considerable thickness is also well known to exist in the earth in the neighbourhood of petroleum springs. Thus, as has been already noticed, in the valley of Noto, in Sicily, is a spring of petroleum, which discharges itself into the lake Palius; the earth above it, even to the surface, being so much bituminized, as to have taken fire by accident, and to have burnt for several months. The connection between these several impregnations appears to be evident. As the resolution of vegetable matter into a bituminous fluid takes place, so in proportion will the adjoining earth become impregnated; and where this change is so complete that a fluid bitumen is formed, the diffusion and absorption will, of course, be extensive, in proportion to its fluidity. The bituminous schist, which is adjoining to beds of coals, is evidently formed of such earths, as have become impregnated by the fluid bitumen, whilst the coal existed in the fluid state of petroleum.

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[*] That water may exist in an intermediate state, between that resulting from the actual combination of the principles which constitute water and their state of complete separation, does not appear to be improbable. In siliceous and other hard bodies, capable of being reduced to a pulverulent form, and in no other way manifesting the least trace of it, its presence is detected by distillation. From the observations of my ingenious neighbour, Mr. Hornblower, it appears, that the current of air from an hydraulic bellows produced a considerably greater effect, in augmenting the intensity and brilliancy of the fire to which its blast was applied, than a similar quantity of air, urged with an equal degree of velocity, by a bellows of common construction. Might not the agitation and intermixture of the air and water produce a partial separation of the principles of the latter, into an intermediate gaseous state; in which the two principles, being less closely united, would act, on their application to the burning embers, with energies somewhat similar to those which the two principles exert when entirely separate. Whether it exists in this partially decomposed, but permanent gaseous state, or entirely decomposed into the two original permanent gases belonging to its constitution, as has been supposed to be the state in which it exists in the atmosphere[*], must be left to future experiment to determine.

[*] Nicholson's Journal, April 1801.

A revision of the several circumstances mentioned whilst describing the situation of coal, and its accompanying strata, will serve not only to confirm the supposed origin of coal, but also to prove the fact of its having at one time existed in a fluid state. The different *partings*, as they are termed, between the top of the coal and the roof, deserve particular notice, on this account. In good partings there sometimes exists a space between the coal and roof, the coal being sprinkled with a powder like charcoal. In this case the previous fluid state may be surely inferred without the least difficulty, the space appearing to be the consequence of the drying and contraction of the matter forming the coal, after the superior stratum, the roof, had acquired a considerable degree of firmness. This inference must be made, almost without hesitation, in other instances, where the parting is perfectly clear; the head of the mass of coal being described, by writers on this substance, as possessing a surface so smooth and polished, as if it had been varnished, or covered by some fluid matter.

In confirmation of coal having existed in a state of fluid bitumen (petroleum), I must remark that this substance is frequently found in the neighbourhood of coal. Thus Mons. Morand, who thought that bitumen was probably the basis of coal, informs us that in the mines of Franche Compté, the bitumen exudes in the form of a sort of *guhr* (tears of the mines).

That the wreck of the vegetable part of the antediluvian world was placed in such a situation as to be continually permeated by water, and subjected to the conversion into bitumen; and that the nascent bitumen would unite with, and afterwards retain a portion of this water, I have not, indeed, been able to present you with actual proof; but have been only able to offer you evidence of a circumstantial nature: trusting, however, that it is of some considerable weight.

Bitumen alone would not, however, accomplish that grand purpose for which nature formed coal; that of supplying future ages with a substance for fuel, which, by a moderate exercise of the ingenuity of man, might be made to burn with almost every degree of intensity; from that which is employed to convey to the human body a grateful sensation, to that which is necessary to fuse some of the untractable metals.

The rapidity with which pure bitumen burns, would not only occasion a considerable waste of it, if it were attempted to be employed for the purposes to which coal is applied; but would also render it so unmanageable, as entirely to prevent its useful application, to even the most ordinary purposes, which coal is intended to fulfil.

To moderate this high degree of combustibility, and so to regulate it, that the consumption of a substance, so necessary to man, should be rendered uniform and œconomical, was therefore required. To accomplish this, the intermixture of some incombustible substance with the petroleum became necessary. But to produce those characteristic properties, by which coal is distinguished from all other substances of the same class, a particular kind of arrangement of the particles of this heterogeneous mass was requisite. It was necessary that the bituminous particles should be so involved, and insulated, on every side, as to be nearly defended from the action of the fire. It was also necessary that the regularity of its combustion should not be disturbed, by the superadded incombustible matter existing in the mixture, in such gross particles, or in so irregular a state of diffusion, as would have been the case, if the earth had remained in it, in the state in which it had subsided along with the sunken vegetable mass.

The arrangement of the respective particles of the mass which would make the nearest approach to the attainment of the required object, would be that in which each individual particle of bitumen would have its combustibility left unimpaired; except so far as its inflammability would have been corrected by the oxygenizement of its carbonaceous part: at the same time that, by the appropriate interposition of some nearly incombustible matter, such a check should be given to the spread of the ignition, of one series of the bituminous particles to another, as should render their combustion sufficiently slow and gradual. Such an arrangement as might thus, *à priori*, have been supposed to be best calculated to produce this effect, may be perceived, to have been actually employed, in the formation of coal.

If a piece of common coal be washed in water, so as to remove from its surface all the minute shattered fragments, which adhere to it, the fingers will be found to be no longer stained by it: and with a lens of very moderate power, or even with the naked eye, it may be plainly seen, that the bituminous matter is disposed in an irregularly laminated structure, and that the horizontal surface of each small and thin stratum is finely coated with an extremely thin film. This film, or pellicle, may also be seen frequently to dip, and pass through the substance of the bitumen; intersecting the horizontal septa nearly at right angles, and thus placing the bitumen in distinct divisions, the *parietes* of which are formed of an incombustible pellicle. This film, in general, reflects tints of a greyish white, but sometimes it appears with the hue of bronze. Frequently it is of a pyritous nature, shining with a bright metallic lustre, or, as in the peacock coal, manifesting a beautiful iridiscent appearance; frequently also, when the pellicle itself is of a greyish white, it will be variegated with bright yellow pyritous illinitions; and sometimes spathous, or pyritous lamina, will be interposed, a quarter of an inch, or even more, in thickness. On inspecting the edges of the coal, each separate lamina will be found to be composed of bituminous concretions, exhibiting the conchoidal fracture, and shining with a considerable degree of lustre.

On letting a piece of coal fall on any hard body, thus breaking it in such a manner as will not direct its fracture, but will allow it to take place in such directions as accord with the natural divisions formed by the interposed films, the fragments will in general be found to assume the form of rhomboids or of parallelipipeds; the very forms which a body, whose parts were thus separated and disposed, might be expected to exhibit, on being fractured.

The separating pellicles or interposed septa, in those specimens which I have examined, appear to be formed of sulphate of lime, containing a small proportion of alumine, and sometimes also of sulphuret of iron. The presence of these substances in coal, is manifested by the analysis which has been made of this substance. Mons. Fourcroy has ascertained that the ashes of coal contain the sulphates of iron, of magnesia, of lime, and of alumine; and, even in asphaltum, both the sulphuric and muriatic acids were found, by du Blé, in union with calcareous earth*.

By such an arrangement of the bituminous particles, and by the frequent interposition of pellicles of incombustible matter, which have been just described, not only is the combustion of coal moderated, but it is likewise so regulated that, in its employment for common domestic purposes, the internal parts of even small portions of coal are so protected, from the too rapid access of the oxygen, that only the external part is actually consumed and reduced to an ash; whilst the other part is rendered a coke or cinder, and is capable of being again employed; and even, with increased advantage, in many culinary and chemical operations. Here then are we presented with one of the many instances, in nature's works, of the obtaining of the most important ends, by a contrivance not less remarkable for its simplicity, than for the certainty with which it accomplishes the desired effect. It also serves to shew that, in every investigation of the operations of nature, the more minute are our inquiries, the more will our admiration be excited by the discoveries which we make. A superficial examination of any of the works of creation must be sufficient to excite our wonder; but an inquiry, successfully employed, in ascertaining the means by face of the earth will here, therefore, at one season, be found teeming in every point with animal and vegetable life; at another season, it will be found richly impregnated with resinous, oily, and other carbonaceous matters, which have been let loose, during the decomposition of so many organised bodies of both kingdoms.

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* How strongly the water, which was diffused through the bituminous mass, was impregnated with these several particles, may be inferred from the frequent presence of calcareous spar in the interstices and cavities of coal. Thus, in a specimen of coal now before me, about nine inches in length, and about three inches in width, the substance of the coal is beautifully intersected by numerous white streaks of spathose matter; and a large interstice, the whole length of the specimen, is covered with very white and perfect crystals of the dog-tooth spar, forming a beautiful contrast with the including coal.

Thus, by the regular decay of the vegetables with which the earth's surface is covered, and of the animals which they nourish, are fit matrices formed, and appropriate nutrition secured, for succeeding generations. By forests falling through age, and obtaining a covering from subsequent perishing vegetables, and being afterwards pervaded by moisture, the formation of peat-mosses are easily accounted for; as well as the light loose earth with which these are almost always covered, according to the poet, who, alluding to the vast profits derivable from the digging of peat, and to the indication of subjacent peat, by the superficial light earth, says,

> Est locus in Batavis, ubi nec gratissimus hæres,
> Terram defuncto non velit esse gravem.
>
> *Epigram seu Enigma de Terra uliginosa*[*].

But we have particularly to contemplate more sudden and extensive changes, wrought by a deluge extending its power over the whole surface of the earth. It is beyond the powers of the human mind to conceive the prodigious changes which must have been effected during this grand revolution. Receive then, with suspended judgment, this slight sketch of some of the probable events of that awful period.

By the spread of this overwhelming torrent over the whole surface of the globe, forests must have been prostrated, mountains broken down, and the waters of the rivers blended with those of the ocean. During the stay of the waters on the face of the earth, vast changes must also have been affected. Long-continued submersion must have rendered the earth so soft and yielding, that the pressure, united with some degree of agitation of this immense bed of water, must have completed the subversion of the forests by which the earth must have been nearly covered. Even during the passing away of the waters, considerable changes would be accomplished. Whilst the waters were separating from the dry land, the librating torrents would form for themselves new channels: their beds, when cleared of their waters, would display vast and extended vallies; and their sides, mountains of an alpine height.

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[*] Epigrammata Constantini Hugenii, lib. i.

By the continuance of the waters, the upper surface of the strata of subverted vegetable matters would necessarily become covered by a muddy deposition, which would subside from the body of water, by which it had been overwhelmed. On the passing away of the water, the light substances which had floated on its surface, amongst which would be various animal remains, would be deposited on the muddy stratum which was already laid on the subjacent mass of vegetable matter. Thus would be formed a soil, which, on the passing away of the waters, would again promote a rapid and luxuriant vegetation.

Such a tract would necessarily long remain free from the interference, or culture of man; and, previous to the complete departure of the water from it, would at certain times be liable to be covered by inundations; and at others, when left dry, would be exposed to the heat of the sun. The plants peculiar to these two different states might also be expected to be produced. Hence equiseta, reeds, and other aquatic plants, would, at one time, fill this spot, which at another would be covered with a variety of filices, and of other plants peculiar to the open and sun-burnt heath.

Should the neighbouring mountains have contained iron, this, dissolved by the various salts with which the water would be impregnated, would be conveyed to spots where the water rested, and where the decomposing organic matters were deposited; and would there be precipitated in the form of a brown oxide: this, uniting with the superior and finer part of the earthy deposit, would cover the decomposing vegetable matter with a stratum which, perhaps, after no great length of time, would become that substance which is known to mineralogists as bog iron ore. But if, instead of the water passing off, it should have long remained, and formed a large and deep lake, then would other strata be successively added to that which has just been mentioned. Sometimes these strata would be furnished by the crumbled particles of the softer rocks, which formed the sides of these immense and newly-formed reservoirs; whilst strata of vegetable matter, furnished by the aquatic plants, or brought by torrents, would be arranged alternately with these. At other times, large masses of harder rocks would fall, undermined: and, broken into pieces by the fall, would be sized and rounded into boulders of various forms and magnitude; or would be so far comminated, as to be rendered the materials of future breccia, the coarser sand-stones, &c. By the pressure of many of these succeeding strata, the lower ones would suffer a closer approximation of their parts. The effects of this pressure are most observable in those strata which have since become schisti, and which contain the flattened remains of both vegetables and animals. The marks of pressure are not, however, observable in all the strata, these effects appearing to be much less general and extensive than might be supposed, arising, probably, from each firmly-consolidated stratum protecting the subjacent strata from the pressure of the accumulating, superincumbent, mass. Other strata would be formed by the coalescing particles of iron, and of argillaceous earth. These now constitute the substances commonly called iron-stone, and which, from their compactness and great degree of specific gravity, have been supposed by many mineralogists to owe their origin to fire.

The strata of deposited vegetable matter, being thus secluded from the air, by alternating layers of dense and compact stony matter, would proceed, uninterruptedly, through the bituminous fermentation; during which it would be constantly permeated by water impregnated with various saline, earthy, and metallic particles, derived from the several strata through which it had filtered. Under the influence of these circumstances its conversion into coal would be completed. Thus would a substance, particularly adapted to the purposes of combustion, be formed, from the *eluvies* of the devastating deluge, and would be providentially heaped up in the subterranean storehouses of nature, to be discovered in after-ages by the curiosity and industry of man, when the spread of civilization, by laying waste the vast forests which covered the earth, should have considerably diminished the stock, whilst the increased modes of consumption should have augmented the demand of fuel.

When the very limited powers of our judgment are considered, which frequently are not even sufficient to satisfy us, respecting the immediate or proximate cause of several of the most common natural phenomena, we should be very cautious in proposing any hypothesis, respecting the operations of nature, unless the regular concatenation of cause and effect can be plainly traced; and the supposed final end is in exact accordance, with our best ideas of utility and wisdom. This caution is particularly necessary, if the hypothesis is intended to point out a regular series of operations, to mark their dependence, and, lastly, to infer the purposes, and motives, which have influenced the Creator, in making this particular arrangement. Without such circumspection, there would be danger lest, measuring the wisdom of God, by the scale of human intellect, inferences derogatory to the divine dignity might be made; and plans and contrivances be imputed to the Divinity, not only unworthy of omniscience, but originating only in misconception, and presumption.

But, it is hoped, that hypothesis which supposes the transmutation of vegetable matter into bitumen and coal, possesses the internal evidence of truth, since it presents to us a scheme, in which the œconomy of nature is exercised, in a manner the most agreeable to the ideas we entertain of a beneficent providence.

Delightful indeed must have been the scene, which the earth must have every where presented, immediately before the deluge. Every hill and valley must have been clothed with luxuriant vegetation. But the moment of apparent destruction arrives: the lofty forests, with which nearly the whole of the earth is supposed to have been covered, are at once levelled: a world, which just before appeared an elysium, is desolated, and rendered one vast mass of seeming ruin. Torn up and carried away, by the force of the tremendous torrent, the trees of the mountains are laid on those of the vallies, and are together buried by the subsequent subversion of the mountains themselves. Reflecting on such a scene of desolation, unproductive of any evident good, the mind hesitates, and feels a painful dissatisfaction at being unable to imagine the origin of such a mass of evil, without depreciating the wisdom, or the power of the Creator.

It is not, indeed, for me, deeply to agitate the abstruse and important question which is here involved; but permit me to observe, that when the power, the wisdom, or the benevolence of God, appears to be deficient, the defect will ever be found in the powers of observation, and reflection of man, which do not enable him to discover the connection, between a comparatively small, or even only apparent, evil, and a really great, and important good.——After a short period the waters pass through their destined channels, and the earth again becomes covered by the delightful verdure of vegetables; fitted for the gratification of man, and for the support of animal life. The vast forests, too, thus buried in the earth, instead of mouldering into an inert and useless mass, still continue to per-

LETTER XXVII.

MINERAL COAL....OPINIONS RESPECTING....SUBTERRANEAN COMBUSTION OF PIT-COAL....COMBUSTION OF PYRITES....MINERAL CHARCOAL.

HAVING already taken some pains to prove, that the formation of coal depends on the process of bituminization, it will of course appear to you, that I have rather an ungracious task to execute, when I now inform you that this letter must be devoted to the description, and history of a substance, MINERAL CHARCOAL, which, though considered, and described as a coal, does not manifest, on the nicest analysis, the least trace of bitumen.

This substance, which possesses most of the external characters of pit-coal, but, at the same time, agrees in all its chemical properties with charcoal, is thus described by Mr. Kirwan*, who, anticipating the discoveries of Guyton de Morveau, conjectured it to be the natural carbonic principle, as pure as nature generally affords any principle.

Its colour is black, or greyish black; its lustre approaching to the metallic; and its hardness, although it yields to the nail, exceeds that of chalk. It possesses no transparency, and breaks into tabular fragments; its fracture being foliated or slaty, and its cross fracture flat conchoidal. It stains the fingers. Specific gravity, from 1.4 to 1.53.

This substance is insoluble in acids. In a strong heat, it reddens, but does not flame; in a crucible, however, a slight bluish flame, but without any sulphureous smell, is observed, undoubtedly from the decomposition of water. Exposed to a porcelain heat for several hours, in a closed crucible, it entirely, or almost entirely, evaporates like diamond. Under a muffle it is almost entirely consumed. Distilled, it yields a small quantity of water; but no air, oil, acid, nor alkali. Mixed with sulphate of pot-ash, it yields a liver of sulphur; and projected on red-hot melting nitre, it deflagrates and alkalizes it: hence, Mr. Kirwan remarks, there is no doubt but it is a combustible substance, possessing both the external and internal characters of mere coal, or charcoal.

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* Elements of Mineralogy, by Richard Kirwan, Esq. 1796, vol. ii. p. 49.

The *Kilkenny coal* is of this species; its fracture being foliated, and its fragments often coated with whitish illinitions. The *culm* of Wales seems a variety of this species, but less pure, differing from it, chiefly, in being more brittle, and emitting, when ignited, a disagreeable smell.

This substance yielded to Dr. Hutton, and the French chemists, a strong corroboration of the opinion they had formed, respecting the changes which bituminous substances, and particularly coal, underwent from the influence of subterranean heat*. Knowing that besides the common pit-coal, rich in bitumen, there existed this substance also, in which no bitumen was discoverable, they considered the former kind, as abounding in the oily matter which had been contained in the various organised bodies, from which it had derived its origin: and concluded, the latter to have been exposed to a considerable degree of subterranean heat, in consequence of which, it had suffered a deprivation, by distillation, of its bitumen; it being thereby left a caput mortuum, or perfect coal. The existence of the purer bitumens, in separate situations, has been also reckoned in evidence of the propriety of this theory. Thus Dr. Hutton mentions, as an instance of the separate existence of these volatilized bituminous matters, a stratum of lime-stone, near Raith, in Fifeshire, which, though but slightly tinged with a black colour, contains bituminous matter like pitch, in many cavities which are lined with calcareous spar crystallized.

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* Theory of the Earth, with Proofs and Illustrations, by James Hutton, M.D. 1795.

Dr. Hutton's opinions respecting the changes produced on subterranean bitumens, by the agency of fire, may be comprised in these two positions; first, That the purer and fluid bitumens are produced by distillation from coal; secondly, That the Kilkenny coal, and other similar natural coke, is the residuum of this distillation. In refutation of the first of these positions, which has been also endeavoured to be supported by most of the French chemists, little requires to be said, except to remark, that the quantity of the fluid, and purer bitumens, naphtha, petroleum, asphaltum, &c. which has been found, far exceeds the proportion of such coal as, with all that diligence of research which so useful an article has excited, has been discovered to have suffered this spoliation. But that this substance is common coal, deprived of its bituminous matter by heat, I acknowledge, seems at least to be probable. When we contemplate the situations in which coal mines are placed, inclosed on almost every side by strong barriers of stone, by which the access of atmospheric air is almost entirely prohibited, we cannot but conclude, that, should a seam of coal become ignited, the coal must be completely charred, as far as its combustion extends. That it furnishes any evidence in favour of all coal having been exposed to the fusing power of heat, I acknowledge I do not perceive; but merely that such particular masses of coal have been subjected to fire. Proving also, that such is the wise provision made in this case, that, although a substance, formed to supply mankind with fuel, should casually be subjected to the premature influence of fire, it shall still continue fitted for the purpose for which it was originally intended; the very material changes, which it has undergone, having even rendered it more highly useful, for certain purposes, than it had been in its original state. Mr. Kirwan, however, who will not allow that the Kilkenny coal has suffered any change by the action of fire, says, " Would not bitumen be found in the neighbourhood of those beds of coal from which it had been expelled ? Would not the sulphur also be distilled from the pyrites found in the coal ? Yet neither in the coal mines of Kilkenny, the coal of which is, of all others, most completely destitute of bituminous matter, nor any where near them, is the least trace of bitumen to be found ; and the pyrites remain in their usual integrity."

Every endeavour to account for the formation of this mineral carbon, meets with considerable difficulties ; neither the Neptunian nor the Plutonian system appearing, in the present state of our knowledge, to be sufficient, separately, to explain the circumstances attending the production of this substance.

As to the operation of fire, it must be admitted, that the combustion of a vein of coal might take place, under such circumstances of prohibition of the access of atmospheric air, as might, most probably, secure the reduction of the coal to a char. The absence of petroleum, or rather, of coal tar, from the neighbouring strata, being perhaps to be accounted for from the escape of the principles of the bitumen, in the form of carburetted hydrogen and carbonic acid gas : the pyrites in these mines might also proceed from changes subsequent to the combustion, perhaps from the infiltration and decomposition of dissolved sulphate of iron, which might have been produced by, and lodged in, the superior strata, by that combustion. It is, however, with hesitation, I venture an opinion on this subject.

The probability of the Kilkenny coal having been thus formed, derives some augmentation from the spontaneous, as well as accidental, burnings of strata of coal, which, even of late years, have been noticed, as having occurred in several parts of the world. Thus Cambden speaks of a coal mine in Newcastle, which was burning for several years; and according to the account of Mr. Jefferson, who wrote in the year 1787, a bed of coal at Pittsburg, in North America, was then burning, and had been on fire since the year 1765*. Another coal-hill, on the pike-run of Monongahela, had then been burning ten years, and had burnt away about twenty yards only. The Abbé Raynal also relates, that a vein of coal was set on fire at Cape Breton, which burnt with great fury.

In the grounds at Benwell, about a quarter of a mile north of the river Tyne, a coal mine took fire at a workman's candle, negligently placed, and continued burning about thirty years, though at first so small, that a proposal was made to put it out for so low a reward as half-a-crown, but it was not accepted. It afterwards acquired such force and strength, Mr. Wallis says, from the kindled sulphurs and bitumens, that it raged with fury, in various directions and depths; sometimes taking its course east and west, and at last to the north, into the grounds of Fenham, near a mile from its first appearance: committing great ravages in its way; only conspicuous by its flame, and columns of smoke, in the night. The eruptions at Fenham were in near twenty places†.

Nor is it from accidents only that combustions of this kind occur. Mr. Williams states that, within a mile of Kirkaldy, in Scotland, in a great plain, called Dysart Moor, the coal, which is there found in plenty, burns almost spontaneously—Sometimes flames are seen in the night, and a black smoke in the day—The inhabitants say, at approach of storms, dreadful hissing noises are heard from the holes and caverns, with a considerable discharge of flame. Nor is it beds of coal only, that a slow combustion would convert to mineral coal, as Mr. Kirwan calls this charred coal; since a similar substance might probably be formed by the burning of peat, the stratum covering which would so regulate its burning, as to secure its charring. In addition to the instances, mentioned in a former Letter, of these accidents, I will relate one, mentioned by Abbé Fortis, who says, " Not many years ago, a fen, near the village of Ostrovizza, was struck with lightning, and, its bottom being turf, it burnt a long time under-ground, though the fire was visible only in the night; after it was extinguished, the whole fen remained black, and the upper soil became barren*."

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* Jefferson's State of Virginia, p. 43.

† The Natural History of Northumberland, vol. i. p. 132.

Indeed the very considerable disengagement of heat, during the decomposition of pyrites, will easily account for the natural accension of so combustible a body as coal, if in union with it whilst such a process is going on. Thus Dr. Jorden, speaking, in his Essay on Mineral Waters, of the properties which coals possess, when they contain much of the pyrites, or, as the colliers say, coal-metal, of heating and even kindling upon the gradual accession of moisture, or the affusion of water upon them, states, that several such accidents have happened at Newcastle; and he particularly mentions a circumstance of this kind having occurred in London, at Puddle-dock. Dr. Plot relates†, that at Ealand, in Yorkshire, one Wilson having piled up many cart-loads of pyrites in a barn of his own, for some secret purpose, perhaps to extract the gold, the roof being faulty, and admitting rain water to fall copiously in among them, they first began to smoke, and at last to take fire, and burn like red-hot coals, so that the town was considerably disturbed and alarmed.

To effect the dissipation of a considerable portion, if not the whole, of the inflammable matter, from vegetable and bituminous masses, a less degree of heat may perhaps be sufficient: such as may neither render the mass, nor the vapours which evolve from it, luminous, but during the darkness of the night. The phenomena described in the following account, related by John Stephens, M.A. in the Philosophical Transactions*, seems to point out such a gradual decomposition of pyrites; and which, by charring the included combustible matter, might be competent to the formation of the peculiar coal here treated of. Mr. Stephens says, "that in the month of August, 1751, the air, having been for some time remarkably hot and dry, was changed of a sudden by a heavy fall of rain, and a high south-west wind. The cliffs near Charmouth, in the western part of Dorsetshire, presently after this alteration of the atmosphere, began to smoke, and soon after they burned, with a visible, though subtile flame, for several days successively; and continued to smoke, and sometimes to burn, at intervals, till the approach of winter; nay, ever since that time, especially after any great fall of rain, thunder and lightning, or a high south-west wind (which drives the sea with great violence against the cliffs, and beats off large pieces of them), the cliffs continue to smoke, and sometimes to burn with a visible flame, which, during the summer months, is frequently observed in the night time. On examining these cliffs, in the year 1759, I discovered," he says, "a great quantity of pyrites, not in any regular strata, but interspersed in large masses through the earth, and which proved to be martial; of cornua ammonis of different sizes, and other shells, but of the bivalve class, which were covered over, and mineralized, as it were, with the pyritical matter; of belemnites, also crusted over with the like substance: and the cliffs, for near two miles long, and from the surface to thirty-five or forty feet deep, even to the rocks at high-water mark, were one bed of a dark-coloured loam, strongly charged with bitumen. Moreover, I found also, he says, a dark-coloured substance, resembling coal cinder; some of which being powdered, and washed in distilled rain-water, upon filtrating the water, and evaporating it to a pellicle, its salts shot into fine crystals, and appeared to be no more than a martial vitriol; one ounce of this cinder-like substance yielding one drachm of salt. I gathered up about one hundred pounds weight of the different kinds of those pyrites, marcasites, &c. which were laid up in a heap, exposed to the air, and every day sprinkled with water: the consequence was, that, in about ten days time, they grew hot, soon after caught fire, burned for several hours, and fell into dust.

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* Travels in Dalmatia, p. 37.

† The Natural History of Staffordshire, by Dr. Thomas Plot, p. 142.

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* Philosophical Transactions, vol. lii. p. 119.

" When the cliffs were observed to burn in the night-time, the flame was plainly perceived by a spectator at a distance; but when he drew near to the place, seemingly on fire, he could perceive a smoke, but no flame. In the day time, nothing but a smoke was perceived, except the sun shined; when the cliffs appeared, at a distance, as if they were covered with pieces of glass, which reflected the sun's meridional rays; but, upon drawing near to the places, where these luminous appearances were perceived, they disappeared, and the cliffs seemed to be covered with smoke, which stunk of a bituminous and sulphureous matter.

" I have also, he says, been an eye-witness of the same kind of flame arising from the Lodes, in Cornwall, especially such as contained a great quantity of mundic and martial pyrites. Three times I have seen this flame arise from the earth in the night, and once in the middle of the day. In the night, a person, standing at a little distance, would imagine that the place was all on fire; and, even on drawing near the same, he perceives himself surrounded with flame, but is not hurt; and, in four or five minutes time, he perceives this flame to decrease, and fall into the earth. In the day time, the flame is of a different colour, and not much unlike the flame which arises from a furnace. There are several mines discovered in this country by these mineral fires, where there were no symptoms of such mines before."

A still more gradual decomposition of pyrites, in which no actual accension takes place, may be sufficient to effect this change in combustible matter, with which they may have previously obtained a tolerably free intermixture. Indeed it does not appear difficult to conceive, that a similar effect may be produced, where large masses of vegetable, or bituminous matter, have been subjected to the action of a strong solution of iron in the sulphuric acid, filtrating into them from a superior stratum of decomposing pyrites: an escape of the hydrogen being thereby occasioned, leaving the oxide of carbon, or charred coal, with accompanying pyrites, in the place of bituminous coal.

Several writers have mentioned, with surprise, the circumstance of a substance having been frequently found at considerable depths, which exactly resembles burnt wood or charcoal; and which many, unable to ascertain its origin, have described as MINERAL CHARCOAL. Wood that appeared to have been burnt was found by G. F. de Oviedo, in earth which did not appear to have been ever dug or disturbed, at a considerable depth, in the mines of Peru*. Dr. Woodward thus describes a specimen in his collection†: "A piece of wood having manifest marks of its having been charred, or burnt by the fire, before it was buried in the earth. It is not unusual to meet with wood, thus burnt, reposited in the bowels of the earth."

In the copper mines of the Ryphean mountains, in Siberia, and in the neighbourhood also of Cazan, the copper is found united with blend, sand, and wood, forming a hard and compact mass. The vegetable parts are so brittle as to be easily detached; the wood being black, resembling a charcoal‡.

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* Purchas's Pilgrim, lib. v. cap. iii. p. 971.

† Catalogue of English Fossils, part ii. p. 19.

‡ Voyage en Siberie, en 1761, par Mons. l'Abbé Chappe d'Auteroche, tome i. partie ii. p. 671.

The Abbé Fortis relates, that in Luzzane, on the side of the bed of the torrent called Gipalova Vrilo, he found the roots and trunk of a tree, three feet in circumference, reduced to a fossil coal. The particularity by which this coal trunk was distinguished, was its having been cut, little more than a foot above the root, by a hatchet, or some other similar instrument, before the marine strata covered it. I leave, the Abbé says, to those who are more knowing than myself, to decide by how ancient a hatchet this tree has been cut, and in what times those lands have been covered by the waters of a sea now far from us, and which has left behind it a prodigious quantity of exotic testacei.—In the accompanying gravel are heavy pieces of lava, sometimes black and sometimes grey, fossil coal, and bituminous scissile earth.

Mr. Cramer, Counsellor of Mines at Altenkirchen, in the second volume of *Der Gesellschaft Naturforschenda Freunde zu Berlin Neue Schriften*, relates, that in the county of Wachtersbach, in the principality of Isenberg-Birstein, under the exterior crust, there first occurs a strong stratum of white and red sand-stone, in alternate order, which extends to the distance of several miles in the neighbourhood. Under this lies a grey argillaceous stone, which feels somewhat greasy, soft, and friable, and is scarcely three inches in thickness. Below this there is a stratum of excellent iron-stone, of equal thickness, the bottom of which consists of solid sand-stone, of a kind of mill-stone, which often occurs in these districts. This iron-stone is different from every other kind in the neighbourhood: it is a compact, argillaceous iron-stone, of a reddish brown colour, and of a rough fracture, sometimes mixed with shells; among which there is found, though very seldom, a variety which has a fibrous fracture, with an almost metallic splendour, and seems worthy of farther examination. When I visited this work, he says, some masses of this compact iron-stone were dug up, which contained charcoal. This charcoal was found loose in the iron-stone, and partly grown into its substance, and adhering to it. By what natural, or artificial fire, this charcoal was burnt, or by what singular revolution it was carried into the depth of from three to four fathoms, and there so intimately combined with the iron-stone that it seems to form one body with it, he observes, no mineralogist can with certainty explain.

The hypothesis which Mr. Cramer formed, respecting this singular, and certainly uncommon subterranean mixture, is, that the charcoal was burnt, in the neighbourhood, either in the usual manner, or by natural fire, and that some fragments of it, by some convulsion of nature, were thrown to the above depth, where they united with the ferruginous matter, and by these means produced the above remarkable phenomenon. On many fragments one can observe the transition of the not completely burnt wood into iron-stone; even the bark of the wood, actually converted into iron-stone, may be clearly distinguished; and the perfectly black natural, or artificial charcoal, possessing all the properties of the charcoal of burnt wood, lay undecomposed in it.—This iron-stone, Mr. Cramer adds, is exceedingly easy of fusion; and so much so, that it is used as a flux for other kinds*.

Pieces of this mineral charcoal are frequently to be seen, in the deep stratum of blue ferruginous clay dug for tile-making, near Hackney-road: an examination of this substance, and of that which forms the stratum in which it is found, seems to point out the circumstance, from which the important change it has experienced has proceeded.

Under about a yard of mould, and as much yellow clay, there is in general found, about this spot, a layer of variously sized gravel, and siliceous sand, extending from twelve to fifteen feet in depth, and coloured in every part by a yellow oxide of iron. Beneath this is the stratum of blue ferruginous clay, which is now dug to the depth of twenty-two feet without shewing any appearance of termination. This clay, which seems to have been the muddy deposit of a standing water through many ages, has in almost every part of it small particles of pyrites, which are sometimes formed into pretty large nodules; these larger masses, in general, investing pieces of charred wood. Similar pieces of wood, but without this investiture of pyrites, are here also frequently met with: the whole mass of this structure appearing to be made up of clay, intermixed with pyrites and altered vegetable matter.

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* Phil. Mag. No. xlix. June, 1802.

In endeavouring to explain these phenomena, the first great difficulty is, to account for the origin of the iron and sulphuric acid, which appears to have made its way from the upper part, and to have percolated through the sand and gravel, leaving, as it passed, a yellow oxide. Could the sulphur, the radical of the acid, and the iron, have been yielded by the resolution of organised bodies on the surface; or——but to ascertain the first point of the mysterious circle is a hopeless attempt. Omitting, therefore, its origin, it must be sufficient to trace the effects of the sulphuric acid, holding a considerable portion of iron in solution, of which here is ample, and undoubted evidence, in these several strata. In the stratum of sand and gravel, the deposit of ochry matter appears not to have been changed by the action of any organic substance; nor do there appear any traces here of animal or vegetable existence, excepting the rarely occurring casts or impressions of *echini*, &c. formed on the siliceous pebbles: which figures must have been impressed, whilst the pebbles were laying in those beds, in which they obtained their induration; and from which they were conveyed, by the current which flowed over this spot, after the lake, which had previously existed, had been filled up. Arriving at the mass of clay, intermixed with decaying vegetable matter; the solution of sulphate of iron must have produced effects similar to these, On meeting with the vegetable matter, which had never been sufficiently secured by incumbent strata, to prevent the escape of its hydrogen, and allow its bituminization, a decomposition of the water, of the particles of vegetable matter, and of the sulphate of iron, must have ensued. The carbon of the vegetable would powerfully attract the oxygen, both of the sulphuric acid and, perhaps, of the water, thus becoming charcoal; whilst the sulphur and the metal, each deserted by oxygen, would unite together, and form a sulphuret, or pyrites; which would possess a degree of metallic lustre, proportioned to the degree of reduction which the metal would obtain, from the application of the hydrogen, separated from the water.

Yours, &c.

LETTER XXVIII.

PYRITOUS WOODS....OPINIONS OF DR. HUTTON AND MR. PLAYFAIR ....IGNEOUS ORIGIN....AQUEOUS ORIGIN EXAMINED.

I CONSIDER your claim as too well founded to allow me to impute to you impatience. You requested from me a history of the substances generally termed extraneous fossils; and during a long correspondence, carried on in consequence of that request, I have not yet given you the history of a single substance, which general opinion allows to be thus classed. The substances on which I have hitherto dwelt, I have taken the liberty, contrary to general opinion, to consider as extraneous; or, as I term them, secondary fossils; and, therefore, must refer you to the arguments which I have adduced, in support of that opinion, for my justification, in detaining you so long, in their examination.

The establishing the right of these to the rank of secondary fossils, is not, however, the whole of what I hope to have accomplished. I have also endeavoured, at the same time, to ascertain the most general basis, or substratum, of vegetable fossils: my success, in this respect, however, still remains to be determined.

The subject of the present Letter cannot but prove highly interesting, being the conversion of wood to a splendid metallic substance; in which, although sufficient traces of its original mode of existence are discoverable, the transmutation is such, that its superior gravity, as well as, often, its lustre, proves that it now contains a considerable portion of metallic matter. To give a slight sketch of the history of these bodies, as far as respects the various appearances they yield, the parts in which they are found, and the nature of the change they have suffered, I shall therefore now attempt.

The vague manner in which the metallization of wood has been hitherto endeavoured to be accounted for, will excuse me for extending this inquiry to a more than usual length. Mr. Walch, who paid particular attention to this subject, says, the wood is, in general, metallized, in those places, where the subterranean heat raises a considerable quantity of metallic vapours; and, upon these vapours meeting with solid bodies, they deposit their metallic particles. Water, impregnated with metallic particles, he also supposes, may convey the particles of metal into the interstices, and cavities of the wood.

It must be confessed, that considerable difficulties are to be opposed, whilst endeavouring to determine the real nature of the operation, by which a substance, which originally existed in an organized state, has been so changed, as to be rendered metallic in almost every part. Chemical analysis, as well as the natural decomposition of these substances, shews that they are composed of a portion of the ligneous substance, in most instances rendered charcoal, intermixed with pyrites, or some saline metallic body. The pyrites are frequently in so considerable a quantity, as to suffer hardly any diminution of its metallic splendour from the intermixed charcoal, which still serves to shew the striæ and circles, which characterised its original structure. An inquiry into the nature of the operation, by which this change has been effected, must necessarily involve in it the question—By what natural operation are pyrites formed? This question should, therefore, first engage our attention.

The formation of native metallic sulphurets, pyrites, or marcasites, has been adduced, by Dr. Hutton, as clearly evincing the agency of fire, and as entirely incompatible with aqueous solution. The Doctor says, speaking of the union of metallic substances with sulphur, "This mineralizing operation is performed by heat or fusion; and there is no person skilled in chemistry, that will pretend to say this may be done by aqueous solution*."

Professor Playfair, who has given his powerful support to Dr. Hutton's theory, speaking of these substances, metals in the form of an ore, mineralised by sulphur, says, "Their union with this latter substance can be produced, as we know, by heat, but hardly by the way of solution, in a menstruum; and certainly not at all, if that menstruum is nothing else than water. The metals, therefore, when mineralized by sulphur, give no countenance to the hypothesis of aqueous solution; and still less do they give any, when they are found native, as it is called, that is, malleable, pure, and uncombined with any other substance. The great masses of native iron found in Siberia, and South America, are well known; and nothing certainly can less resemble the products of a chemical precipitation. Gold, however, the most perfect of the metals, is found native most frequently; the others more rarely, in proportion nearly to the facility of their combination with sulphur. Of all such specimens it may be safely affirmed, that if they have ever been fluid, or even soft, they must have been so by the action of heat; for to suppose that a metal has been precipitated, pure and uncombined from any menstruum, is to trespass against all analogy, and to maintain a physical impossibility*."

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* Theory of the Earth, vol. i. p. 63.

In a science like chemistry, in which, from the multiplicity of its subjects, and of their operations upon each other, important discoveries are daily being made, change of opinion must, necessarily, be frequently submitted to, by the most intelligent. Hence also it happens, that apparently established theories, of the most learned men, are sometimes subverted by those whose general knowledge in the science is much less considerable, but whose application of some recent discovery has happened to have been fortunate. Thus the opinions entertained by Dr. Hutton, and by Dr. Playfair, respecting the formation of pyrites, and the precipitation of pure metallic substances, I trust, will be no longer tenable, when compared with the ingenious experiments and observations of still more recent date.

The union of metals with sulphur, without the aid of fire, is discoverable in many instances. A familiar instance is the violet tarnish which attaches itself to polished silver; and which, being allowed to accumulate, will form a crust which may be separated by bending the silver, or striking it with a hammer. This pellicle has been examined by Mr. Proust, who asserts it to be a sulphuret of silver. The common sympathetic inks, formed of metallic solutions, the writing of which, before invisible, is immediately darkened by sulphuretted hydrogen, is also an instance of the union of metal and sulphur, in the moist way. So also is that kind of shining pellicle which forms on wainscots, painted with white lead, and which have been exposed to the influence of sulphuretted hydrogen.

An observation of Dr. Thompson, in his excellent System of Chemistry, affords us very decided evidence on the question which we are about to discuss; which is, Whether the natural combinations of sulphur with the metals are effected, by means of fusion by heat, or by solution by water? Speaking of a combination of sulphur with copper, he says, "This compound may be formed by mixing copper filings and sulphur, and making them into a paste with water, or even by mixing them together, without any water, and allowing them to remain a sufficient time exposed to the air, as I have ascertained by experiment*." This point is also illustrated by the well-known artificial earthquake of Lemery, in which a mixture of equal parts of iron filings and of sulphur, being moistened with water, and buried in the earth, is said to undergo so considerable a degree of expansion, as to make the earth, over it, heave and crack, in several places; from which even fire is said sometimes to burst. Fourcroy, indeed, states, that this experiment did not succeed with Bucquet. But, whether the experiment succeeded to the extent described by Lemery, or not, is by no means essential to our inquiry, since it is sufficient for our purpose, that, when the experiment is made on a very small scale, the mixture heats and swells, sulphuretted hydrogen escapes, and the more fixed principles enter into intimate union.

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* Illustration of the Huttonian Theory, p. 58.

Perhaps neither of the above experiments afford an instance of the union of the pure metal and sulphur: in the latter experiment it seems obvious that this is not the case; and in that related by Dr. Thompson, it appears highly doubtful. Still an examination of the changes which may be supposed to be effected, in these experiments, will place the subject in a more clear point of view. The water is undoubtedly decomposed: its oxygen combines with the metal and with the sulphur, forming a metallic oxide and the sulphuric acid; and these uniting, form a solution of the metal in the sulphuric acid. The separated hydrogen attaches to itself, in its nascent state, a portion of sulphur, and becomes sulphuretted hydrogen gas. Admitting that, in neither of these instances, an union of the two simple substances, the metal and the sulphur, is proved to take place; still, I trust, these experiments shew that a saline combination of these two bodies may be formed, in subterranean situations, merely by the aid of water. This being ascertained, it remains to discover, whether from this compound, and the other substances necessarily present, a metallic sulphuret is not likely to be formed.

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* A System of Chemistry, by Thomas Thompson, M.D. vol. i. p. 117.

The changes which we are to contemplate, then, are those which would take place in a saline metallic solution, exposed to the influence of sulphuretted hydrogen, and the surrounding carbonaceous substances. By the addition of sulphuretted hydrogen to solutions of the metals, it has been found that a considerable precipitate ensues; and the precipitate thus made, is found to be compounded of the metal and the sulphur. The sulphuret thus precipitated is black from silver, yellow from bismuth, brown from copper, &c. Thus also, in subterranean situations, similar effects ensue from the agency of the sulphuretted hydrogen on the solution of the metal. The action of a double affinity is exerted. The dissolved and oxydated metal, as well as the sulphuretted hydrogen, suffers decomposition. The sulphuretted hydrogen being separated into its two constituent principles, hydrogen and sulphur, the former unites with the oxygen, which had oxidated the metal and had contributed to its solution, abstracts it from the metal, and with it forms water; whilst the latter principle, the sulphur, deserted by the hydrogen, combines with the metal, thus nearly freed of its oxygen, and reduced, and forms with it a sulphuret, which is precipitated.

Iron, water, and sulphur, either now exist, or have left traces of their existence, in almost every subterranean situation; and there is no difficulty to oppose the supposition, that, in such situations, changes and combinations might have ensued, resembling those which we have just described. One material difference would, however, arise; the sulphuretted hydrogen, prevented from escaping, must have penetrated, and forcibly exerted its influence on, every particle of the metallic solution. This would also be acted on by the surrounding, as well as, by the mingled, carbonaceous, and earthy or alkaline matter. The oxygenized sulphur and metal, thus acted on, at once, by these deoxidating powers, must each have given up the portion of oxygen attached to them; which, with the hydrogen, would form water; with the carbon, oxide of carbon, &c.; whilst the pure metal and sulphur, entering into intimate union, would form pyrites, possessing a metallic lustre.

It is here proper to remark, that the very ingenious experiments of Mrs. Fulhame shew clearly, the powerful influence of water, in promoting the reduction of metals, and in giving to them their peculiar lustre, at a temperature, even below that which the atmosphere ordinarily possesses*.

Hence it appears probable, at least, that the formation of the native sulphurets may take place, independent of the action of fire; and M. Proust, and our celebrated countryman, Mr. Davy, are of opinion, that the native sulphurets are actually formed, in consequence of a similar decomposition of different solutions of metals, by their combination with hydrosulphurets. It must, however, be remarked, that some of the metals are not thus precipitated by the addition of sulphuretted hydrogen alone; since when the metals are reduced to their *minimum* of oxygen, in consequence of its subtraction by the hydrogen, they retain the last portion of it with a considerable degree of power, and are thereby prevented from entering into union with sulphur. The addition, however, of an earth, an alkali, or the carbonaceous matter, so abundant in the earth, takes from the metal this portion of adhering oxygen, leaving it pure, and free to enter into combination with the sulphur. In justice to the supporters of the Vulcanian theory, it must be also remarked, that essentially different properties, both physical and chemical, distinguish the pyrites, or native sulphurets, from the artificial or factitious. Their crystalline forms, their peculiar splendour, and their iridiscent investiture, yield matter, indeed, for pertinacious argument, on both sides of the question. But, surely, the circumstance of these crystals being found, often, fast imbedded in so combustible a body as bitumen, speaks strongly in favour of their aqueous origin. Jet is frequently found containing them, or being closely invested by them, and at the same time manifesting no marks of having been acted on by heat; which would surely have been the case, if their formation, which must have been at the time of their fixing themselves in, or attaching themselves to, this substance, had been effected from a substance, in a state of igneous fusion. Their splendour, and their iridiscent surface, appear also to be, at least, as easily accounted for by the agency of water, as by that of fire. Mrs. Fulhame has detailed some very pleasing, and ingenious, experiments, which bear very strong evidence in favour of this opinion of their aqueous origin. This lady impregnated pieces of silk with solutions of various metals, and exposed them, wetted with water, to the action of hydrogen, sulphuretted hydrogen, &c. in consequence of which, they became covered by films of reduced metal; which sometimes, like the native sulphurets, displayed a variety of most lively colours. Even those metals, which were not capable of being precipitated, by the addition of sulphuretted hydrogen to their solutions, in this manner obtained their metallic splendour*.

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* An Essay on Combustion, by Mrs. Fulhame, p. 178.

By these experiments, we are undoubtedly taught, that hydrogen, as well as sulphuretted hydrogen, is capable of reducing the metals, even in the ordinary temperature of the atmosphere; that water promotes these reductions in a very remarkable manner; and that these reductions of the metals are accompanied by a variety of colours, resembling those which frequently mark the surfaces of the splendid natural sulphurets, or pyrites.

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* An Essay on Combustion, p. 36.

A series of experiments, ascertaining the effects of hydrogen and sulphuretted hydrogen on various solutions of the different metals, aided by the deoxydating powers of carbon, alkalies, and earths, would, it seems reasonable to expect, manifest, in the hands of the able chemist, that the formation of the brilliant, crystallized, metallic pyrites, has depended on aqueous solution. But the vast mass of materials, the great quantity, as well as the density of the superincumbent strata, which must necessarily prevent any escape of the sulphuretted hydrogen; and the long continuance of this substance, in contact with the other principles, must give so superior a degree of energy to the natural processes, by which these substances are formed, as, perhaps, would leave to art, only the power of approximating to their result.

A fair inquiry into what would be the probable result of the mixture of those substances, which appear to constitute pyrites, and the strata in which they are found, reckoning according to the known affinities of bodies, must be well calculated to assist our judgment, respecting the mode of formation of the natural sulphurets. The substances, with which pyrites are most commonly found to be associated, are those, the formation of which, appears to have depended on the decomposition of organized matter; such is the substance (jet) which led to the present discussion; such is coal, carbonate of lime, sulphate of lime, &c.—but, since the changes are nearly the same which happen in all these instances, the examination of what takes place in one will be sufficient; and, as it may serve further to illustrate the history of bituminous substances, to which our last Letters have been principally devoted, we will consider what is likely to have taken place during the formation of pyrites, in the neighbourhood of substances of this kind.

The altered vegetable matter, or bitumen, you will recollect, is a substance composed chiefly of carbon and hydrogen, with a small portion of oxygen; if then to this substance a solution of iron in the sulphuric acid has been added, we may readily suppose that, it would produce the following changes. From the great avidity with which carbon attracts oxygen, it is just to conclude, that the large quantity of this principle, which is contained in the fluid bitumen, would attach to itself the oxygen of the sulphuric acid, forming therewith either the carbonic oxide, or carbonic acid. The iron and sulphur would thus be liberated from their former combinations, and would, as has been already noticed, rush into new; the sulphur and iron, reduced to a state of purity, would in this state unite together, and form the splendid pyrites; whilst, as has been already observed, their colour, as well as their brilliance, would be likely to be augmented by the hydrogen.

Believing, therefore, that I have shewn, at least, the probability of pyrites, in general, owing their origin, contrary to the opinions of Dr. Hutton and Mr. Playfair, to solution in a menstruum; it becomes now necessary to ascertain, whether the explanation of the mode of their formation will also apply to that particular kind of pyrites, which first led us to this inquiry; namely, masses of a metallic substance and lustre, bearing the indisputable marks and character, of having derived their primitive form of existence, from the energies of vegetable life.

I have already furnished you with some particulars, respecting the form and appearance of pyritous wood, as well as, concerning the situations in which it is commonly found. But as the following account, written upwards of a hundred years since, by Pillingen, whilst treating of the bituminous wood of Meizlibizen, is exceedingly particular and comprehensive, and was written, without the intention of supporting any opinion resembling that which I have here advanced, I have laid it before you, that it may serve as a test, to shew how far the conjectures which I have formed, respecting its formation, are supported, or opposed, by the circumstances under which this substance is found. A pit, he says, was lately dug in the declivity of the mountain, directly to the vein of bitumen, for the more easy extraction of the substances which were dug. Here they first found, for about three feet from the surface, common earth, with which a small portion of sand was mixed: they then dug, to the depth of two orgyia, through a vein of very fine clay, which was sustained by a firm sand, impregnated throughout, and blackened by bituminous vapours. At last, when they came to the surface of the bituminous earth itself, behold! pyrites of a most uncommon form presented themselves to view; so fabricated had they been in the bowels of the earth, that their external appearance, in every respect, agreed with that of decayed wood. Other portions had other appearances; for some resembled stakes; others were so incircled by the knots of branches, &c. as to appear like smooth, cylindrical, and oblong sticks: some again, hollowed out, were woody on the concave inner surface, whilst the external and convex surface was brassy; others were turned, twisted, surrounded, and enveloped in such various fantastic forms, that the most expert artist could hardly have depicted them all. Lastly, some were only partly pyritous, and others were formed entirely by a very hard and heavy pyrites of a silver hue. By a reference to Plate VI. Fig. 1, 23, 27, and 29, a more correct idea may, perhaps, be obtained of the forms which Pillingen here describes.

In a former part of our inquiry, it was endeavoured to be proved, that bituminization is the first essential process, in the mineralization of vegetable matter: and now, I trust, it has been shewn, that the farther mineralization, the metallization of vegetable matter which has been thus bituminized, is very likely to result from its union with certain substances which are, or have been, present, in a state of fluidity, in most subterranean parts of this globe. Reflection on the changes which must take place in wood softened by the bituminous fermentation, and permeated thoroughly by a solution of iron in the sulphuric, or sulphureous, acid, will enable us to form a more correct judgment on this point. These changes would not much differ from the following. The abundance of carbon, possessed by the bituminous wood, would, as has been already remarked, occasion a deoxydation of the metal, and of the sulphur, which had been carried into contact with it, in a state of solution; the greatest part of the carbonaceous matter itself becoming an oxide of carbon, or charcoal, in consequence of this accession of oxygen. Repeated minute examination of metallized woods have clearly shewn to me, that their structure is exactly agreeable to this supposed mode of their formation. The circles and striæ, which give the characteristic appearance of wood to these substances, are evidently formed of the ligneous fibres converted to charcoal, whilst all the intermediate spaces are filled with the brilliant metallic matter.

According to the hypothesis, here endeavoured to be supported, the vegetable substance, at first, suffers a thorough penetration with moisture; it then is submitted to the influence of the process of bituminization, by which it passes through various degrees of softening, even in some instances amounting to liquefaction. The last change which it undergoes is produced, during that softened state, by the addition of the saline metallic solution, of which we have just been speaking. From this long continuance, in a softened state; and from the pressure of the superincumbent matters, we may readily account for this species of mineralized wood being found, almost always, in a compressed state, and for its having undergone this degree of compression, without having suffered any degree of fracture.

I do not, indeed, wonder at the scepticism which you say our friend Wilton displays on this occasion; since several very learned men have been induced, by a consideration of this circumstance, its oval compressed form, differing so much from the round shape of common wood, to believe it to be intirely of subterraneous origin; and that this compressed form was the grand characteristic of wood of subterranean growth.

But in many specimens of this kind of wood, such as those at Plate VI. Fig. 1, and Fig. 7, so few of the ligneous fibres are discoverable, that a section of them displays an almost uninterrupted metallic surface. To explain this circumstance, it is only necessary to consider that, in this case, there must have been a loss of the ligneous fibre, which may be easily supposed to have taken place, not only by the mechanical action of the water, whilst passing through it; but also at the time of the formation of the pyrites, when some of the carbonaceous particles undergoing a still higher degree of oxygenation, and assuming a gaseous form, are employed in the formation of carbonic acid; whilst other portions, uniting with hydrogen, might contribute to the formation of carburetted hydrogen.

I find myself, I acknowledge, much more disposed to concur with him in his opinion, that the frequent discovery of a metallic substance, in a vegetable form, might have furnished the poet with the idea of the transmutative power, with which he favoured the Phrygian king. The following lines seem to corroborate the opinion:

> Vixque sibi credens, non alta fronde virentem
> Ilice detraxit virgam: virga aurea facta est.
> Tollit humo saxum; saxum quoque palluit auro.
> Contigit et glebam; contactu gleba potenti
> Massa fuit. Arentes Cereris decerpsit aristas;
> Aurea messis erat. Demtum tenet arbore pomum;
> Hesperidas donasse putes.
>
> METAMORPH. lib. xi. l. 108.

There are, undoubtedly, numerous appearances, which would lead to the thought of such a transmutative power. Besides stones and earth, we have just seen a realization of the metallic twig; and shall have occasion afterwards to point out some specimens, which display such appearances, as have occasioned very learned men to adduce them, as instances of the conversion of corn and fruits, into a metallic substance.

You will, I suspect, deem this letter too long; in apology, I must remind you, that the task which I have endeavoured to perform is of importance, and, in attempting to establish the aqueous origin of pyrites, I have had to oppose those opinions, which the learning, and the zealous exertions, of their promulgators, have stamped with the highest authority. The strong ground, on which the opinion here opposed, is supposed to be established, may be gathered from the words of Mr. Playfair, who, speaking of pyrites, asserts it to be "a substance that is, perhaps, more than any other, the decided progeny of fire*."

Yours, &c.

LETTER XXIX.

PETRIFACTION......THEORIES RESPECTING......SUBSTITUTION..... ADOPTED BY WALCH, KIRWAN, DAUBENTON, FOURCROY, &C. ....THEORY OF DR. HUTTON AND MR. PLAYFAIR.

ALTHOUGH the truth of your daughter's and our friend's observation must be admitted, that you have been detained a long time from the consideration of the grand object of your inquiry, the nature and formation of *petrifactions;* yet I will not, for a moment, admit the justice of the charge, that this has been done unnecessarily. On the contrary, I flatter myself that it will appear, that the process of bituminization, on which we have so long dwelt, has been a necessary preparatory process to that of petrifaction, in most of the vegetable substances, which have undergone this species of change. But, as the opinion I propose to offer, respecting the petrifaction of vegetable bodies, differs materially from the theories which have been framed by those, who are deservedly considered to be the first authorities, in inquiries of this kind, I think it necessary, in the first place, to give you a sketch of those theories; and then to lay before you that hypothesis, which, according to my judgment, accords best with the several phenomena which these bodies yield.

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* Page 33.

The earliest attempt to account for the petrifaction of wood, on chemical principles, proceeded on the idea, that the fixed, earthy, parts of the wood, deprived of their watry, oily, and volatile parts, on being penetrated by the lapidific fluid, would arrest the stony particles; and thereby so secure their arrangement, that the substance thus produced should exactly represent the form and structure of wood. That the mere earthy particles of a vegetable should thus abide together, and continue in their original form, after being deprived of those particles, by which they had been held together; and that they should, even after the total removal of these connecting particles, instead of becoming displaced themselves, stem the percolating particles of earth, and be able so to retain them, that they should, combined, faithfully represent, as many specimens do, the original peculiarity of structure of the wood, was an opinion fraught with so many obvious difficulties, that another mode of explanation was soon adopted.

The next theory which was proposed, with the hope of accounting for these changes, was that of a SUBSTITUTION of stony, in the place of the organised, matter, which was supposed by many of those who adopted this opinion, to be entirely removed. Thus Berthold says, petrifaction is not a metamorphosis into stone, but a removal, by putrefaction, or a precipitation of the vegetable, or animal matter; and a substitution of stony matter, in the same manner as happens, in metals—copper being, for instance, sometimes thus substituted in the place of iron[*]. Mr. Walch also, in the supplementary part of Knorr's splendid work on this subject, declares his adoption of this opinion to its fullest extent. Different species of petrified woods, he says, teach us that all the particles, even the finest, constituting the substance of any extraneous body, may successively disappear, and be replaced by foreign heterogeneous particles, with so much regularity, that the body, which is produced from them, may possess, perfectly, the form of the original body; preserving all its characters, and at the same time not retaining any at all *(aucune de toutes)* of its original particles[†]. To the process by which this change is accomplished, Mr. Kirwan, believing petrifaction to be thus performed, applies the term, SUBSTITUTION; and describes it as—" the introduction of stony, and sometimes of metallic substances, into organic bodies, whether of the vegetable, or of the animal kingdoms, in proportion as the particles of these organic substances are destroyed by putrefaction, so as to assume the place, and, consequently, the form and figure, of these, as if cast in the same mould. The mineral substances, thus moulded, are," he says, " in the most proper sense of the word, called PETRIFACTIONS[‡]."

Mons. Daubenton is of opinion, that petrifaction only takes place in those bodies, whose composition is such, that a part of them already possesses a stony hardness. Such, he remarks, are the crustaceous coverings of some animals, shells, bones, scales, madrepores, &c. In these substances, composed of a stony, and of a cartilaginous part, he thinks the following change may ensue, on their being long left in a humid situation. The earthy part will separate, and fall away from the cartilaginous part; and if the lapidific juice meet with a body in this state, the earthy particles will enter into the cavities thus left in the cartilaginous part, and, by filling them, accomplish the petrifaction in such a manner, as to give the body the appearance of being still organised.

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[*] De Rebus Petrifactis, &c.—à Dan. Gothilf. Bertholdo. 1766.

[†] Recueil des Monumens des Catastrophes que la Globe de la Terre à essuiés, &c. —commencé par Mons. Wolfgang Knorr, continué par ses Héritiers, avec l'Histoire Naturelle de ces Corps, par Mons. Jean Ernest Emanuel Walch, 1775, tome iii. Pref.

[‡] Geological Essays, by Richard Kirwan, Esq. p. 137.

With respect to the apparent petrifactions of wood, fruits, &c. he supposes them to be formed in the moulds which have been left, by those substances, in the surrounding earth, the external surface of these bodies retaining the exact impression of the surrounding mould. But sometimes, he observes, we discover the marks of the internal structure of the wood; and, to account for this, he adopts, with Mr. Kirwan, the idea of substitution. Here, he says, the water carries away, gradually, the ligneous fibres, and as gradually deposits, in their places, the stony particles; which are necessarily disposed in the same order, and in the same form, with those of the ligneous parts, which have been removed; since they have been distributed in the same points, and have been moulded in the same cavities, which the molecules of the decayed wood have left. All the substance of the wood is thus, by degrees, removed, and its place exactly filled by a stony substance, bearing the exact appearance of the wood itself. These stones, then, he says, are, in fact, not petrifactions, but only stony depositions which have received the impressions of different parts of the wood: and he concludes, that there is no vegetable substance which can become petrified; and that petrifaction can only take place in animal substances, of which a part already possesses a stony hardness. To prevent any mistake on this subject, he observes, that petrified wood should possess the distinctive character of wood, by possessing the medullary productions. It is not sufficient to see concentric layers, it is necessary there should be also lines traversing these annual layers; as they are beheld in the transverse section of a tree, from the pith to the bark, and in some trees, as the cork and the green oak, even in the bark itself*.

The opinions of Mons. Fourcroy, on this subject, very much resemble those of Mons. Daubenton. The layers, he says, of fossil wood, penetrated by water, lose a portion of their dissoluble, mucilaginous, and extractive matter, with a part of the hydrogen, which they contained. Hence they approach to the state of a pure wooden skeleton; the external substance of the woody fibres being even decomposed, and taking on the colour and appearance of charcoal. It appears, he says, in fact, that, although still woody, the fossil wood is approaching to destruction; and that a still longer stay in the earth would destroy it entirely. With respect to petrified wood, or other vegetable matter, he remarks, it is a great error to consider it, as a conversion of vegetable matter into silex, as the term seems to imply. There exists, he says, to be sure, silicified fossil matters, which present to our view, not only the texture of wood, in general, but that even of particular kinds of wood: but the greater part of such specimens are, he thinks, merely pieces of jasper, the fibrous appearance of which imitates that of wood. Even in those specimens where, besides concentric layers, the medullary prolongations are seen spreading from the centre to the circumference, and which is, he thinks, the only incontestable proof of the specimen having been wood, it is not to be imagined that the original woody substance, retaining its form, texture, and dimensions, is converted into siliceous matter: it is necessary, he says, to conceive otherwise of fossil bodies, bearing the marks of organization. Wood, leaves, fruit, and all other kinds of vegetable matter, improperly said to be petrified, have been gradually destroyed, almost atom by atom, within the wet earth, where it has left a hollow mould, which becomes exactly filled by the siliceous earth which the water has conveyed thither. Thus it really is not a petrified wood, but only a substitution of siliceous matter, mixed with other earths and metallic oxides, in the place of the wood. This species of silification is then, he adds, a proof of *the complete destruction of the vegetable matter, and of the disappearance of whatever constituted its elements*[*].

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* Leçons Normales, tome iii. Observations sur les Petrifications.

Innumerable objections oppose themselves to the attempt, of accounting for the lapidification of vegetable substances, by this process of substitution. In what manner can it be supposed that a line, smaller than a hair, extending from the centre of a piece of wood to its circumference, can have its original component parts taken away, and their places so exactly filled by earthy particles, merely deposited from water, as to preserve its continuity unbroken? If this should be even imagined as possible, in the instance of a single line—can it be admitted that such a regular abstraction and supply, imitating exactly those processes only known to be performed by organised parts, could thus take place, through every series of the vessels, and every fibre of the decayed wood; and thereby produce an appearance, not in the least differing, from that of the original wood itself. But were even this to be claimed as possible, and were it allowed that the form of the wood might be thus preserved, and its structure imitated; how should we, on this hypothesis, account for the original colour of the wood being exactly retained? Can it be supposed that the original molecules being thus removed, that the added particles of earth, derived from the surrounding mingled mass, should be so regularly placed, that the arrangement, and blending, of the variously coloured particles should yield an exact imitation of all the different hues, and of the disposition of the characteristic shades of colour, of the original wood. In whatever point of view, therefore, the subject is seen, the impossibility presents itself, that such a process, the fortuitous disposition of the atoms, by which such a substance would be formed, could perfect so exact a resemblance in the figure, structure, and colour of an organised body, that the eye, unaided by the touch, should not be able to discover the difference.

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[*] Systême des Connoissances Chimiques, tom. viii. p. 255.

The theory of Dr. Hutton next demands examination. The impregnation of siliceous fossil wood, he supposes to have been effected by injection with flint, in a state of simple fusion by fire. "With whatever different substances," he says, "the woody body shall be supposed to have been penetrated, in a state of solution by water, the regular structure of the plant would still have remained, with its vacuities, variously filled with the petrifying substances, separated from the aqueous menstruum, and deposited in the vascular structure of the wood. There cannot be a doubt with regard to this proposition; for, as it is, we frequently find parts of the consolidated wood, with the vascular structure, perfectly in its natural state and situation; but if it had been by aqueous solution that the wood had been penetrated and consolidated, all the parts of that body would be found in the same natural shape and situation. This, however, is far from being the case; for while, in some parts, the vascular structure is preserved entire, it is also evident, that, in general, the woody structure is variously broken and dissolved by the fusion and crystallization of the flint*."

The first proposition which the Doctor lays down, and with regard to which, he says, there cannot be a doubt, is that "*with whatever different substances the woody body shall be supposed to have been penetrated, in a state of solution by water, the regular structure of the plant would still have remained, with its vacuities, variously filled with the petrifying substances, separated from the aqueous menstruum, and deposited in the vascular structure of the wood.*" The test which the Doctor has here proposed for ascertaining, whether the petrifaction of wood is, or is not, an operation dependent on aqueous solution, is certainly the best adapted of any that could be devised; for, as is implied in the Doctor's statement, if the regular structure of the plant remain, with its vacuities, variously filled with the petrifying substances, separated from the aqueous menstruum, and deposited in the vascular structure of the wood; then the change cannot have been effected by any other means, but an aqueous solution of the impregnating matter. Now, not to dwell on the general evidence, which, I think, is yielded by almost every specimen of siliceous wood; I will urge the more direct evidence which is afforded by a particular specimen I possess. In this specimen, impregnated with silex, either by gradual decay, or by the mechanical action of water, the fasciculi of longitudinal fibres, which appear to have retained their natural colour, seem to have been so loosened in their attachments, as to have hardly adhered together, previous to their impregnation; and in some parts very considerable vacuities have been formed. In its present state, exceedingly small siliceous crystals invest every fasciculus, and line every interstice and cavity, but without proceeding so far as to entirely obliterate them, or in the least to alter the regular structure of the wood; all the remaining parts of which appearing to retain their natural shape and situation.

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* Theory of the Earth, vol. i. p. 61.

That such an investiture of crystallization, spreading almost over the whole surface, could have been thus regularly disposed, from an injection of flint rendered fluid by heat, without obliterating the small cavities, and interstices of the wood, by the introduction of the melted matter, and without affecting the regular structure, or even the colour of the wood, is hardly to be conceived; whilst the supposition of the siliceous matter having been gradually applied, from an aqueous menstruum, offers us, comparatively, no difficulties to encounter.

In the concluding part of the Doctor's observations, two positions are laid down: first, that if it had been by an aqueous solution, that the wood had been penetrated, and consolidated, *all* the parts of that body would be found in the same natural shape and situation; secondly, that the woody structure is variously broken and dissolved by the fusion and crystallization of the flint. With respect to the first of these positions, it certainly does appear to be untenable, since many specimens of fossil wood bear the strongest marks of having suffered much from decay previous to their impregnation; and surely, from long maceration and agitation in water, the pressure of surrounding hard bodies, and the numerous accidents to which this wood may have been exposed, previous to its impregnation, it would not be surprising, if, after its consolidation, by the means of an aqueous menstruum, *all* its parts were not found in their natural shape and situation. On the other hand, specimens are frequent, in which the natural shape and situation of the parts are preserved throughout, even to fibres, distinguishable only by the aid of glasses. Here again it may with propriety be questioned, whether, in this case, the injection of silex, melted by heat, could possibly have taken place in this wood, without entirely destroying its structure, as well as colour. This breaking and dissolution, in some parts of a specimen, the Doctor, in the second position, considers as attributable to the fusion and crystallization of the flint. How this dissolution of the parts of the wood may be accounted for, has been endeavoured to be shewn above, in part; and other causes, supposed to be equal to the production of the same effect, will be soon pointed out. In the mean time, it may be sufficient, to point out the difficulty of supposing, the injection of the melted flint occasioning the destruction of the vascular structure, in one part of a specimen; whilst in another part of the same specimen, consolidated in the same manner, the structure has suffered little, or no injury.

Professor Playfair states that, " on examination, the siliceous matter is often observed to have penetrated the wood very unequally, so that the vegetable structure remains in some places entire; and, in other places, is lost in an homogeneous mass of agate or jasper. Where this happens, it may be remarked, he says, that the line which separates these two parts is quite sharp and distinct; altogether different from what must have taken place, had the flinty matter been introduced into the body of the wood, by any fluid in which it was dissolved; as it would then have pervaded the whole, if not uniformly, yet with a regular gradation*."

Mr. Playfair here undoubtedly speaks, of specimens which he has either himself seen, or of those, the description of which, he conceives, warrants this account. My objections here must be necessarily feeble, being only of a negative kind. During the perpetual examination, for several years, of specimens of fossil wood, I can say, that I never yet saw one in which the line separating these two parts of the specimen was quite sharp and distinct, and different from what must have taken place, had the flinty matter been introduced into the body of the wood, by any fluid, in which it was dissolved. On the contrary, in numerous specimens now before me, in which the fibres of the fossil wood are in some parts distinct, and in others lost, I seek in vain for any line of distinction, as to the penetration of the wood with siliceous matter; but see, in all, no difference whatever, in this respect, in that part where the structure is confused, or where it is distinct; nor do I find the least reason to suppose, that the silex has not pervaded the whole, in the most uniform manner.

"In those specimens of fossil wood that are partly penetrated by agate, and partly not penetrated at all," the Professor says, "the same sharpness of termination may be remarked, and is an appearance highly characteristic of the fluidity produced by fusion*." Here I have again to lament the never having had the opportunity of seeing a specimen similar to those which are here alluded to. I possess several specimens of agatine, opaline, and jasperine woods, the appearance of the external parts of which very nearly resemble that of unchanged wood; but examination soon shews that these parts have also been pervaded by the silex. That such specimens do not exist, it is not my intention to assert; it is quite sufficient to remark, that such specimens would only prove that the petrifying matter had only been applied to one particular part of the wood; a circumstance of which there certainly exists no reason to prohibit the occurrence, in the case of the application of an aqueous solution of petrifying matter.

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* Illustration of the Huttonian Theory, p. 25.

Mr. Kirwan, indeed, quotes an account, that the Emperor of Germany, being desirous to know the length of time necessary to complete a petrifaction, obtained leave from the Sultan to take up, and examine, one of the timbers that had supported Trajan's bridge over the Danube, some miles below Belgrade. It was found, it is said, to have been converted into an agate, to the depth only of half an inch; the inner parts being slightly petrified, and the central still wood*. What authority is due to this account, I pretend not to determine; but must acknowledge, that no circumstance, to which I have arrived at the knowledge of, would have induced me to have expected such an event. If the fact be so, it not only is an additional answer to the reasonings of Mr. Playfair, but proves, as Mr. Kirwan observes, that siliceous particles are soluble in water, are taken up by wood, and that petrifaction is carried on, under appropriate circumstances, in modern times†.

Having sketched the outlines of those hypotheses, by which the process of the petrifaction of vegetable matter has been endeavoured to be explained; and having also stated those circumstances which induce me to hesitate, at admitting their sufficiency, I shall, in my next, venture to offer a different explanation of this process, and shall then proceed to examine, whether it agrees any better with the appearances which these substances yield.

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* Juste Gesch. des Erdkorpers, 267. 1 Gerh. Gesch. 222.

† Geological Essays, p. 140

Yours, &c.

LETTER XXXI.

THEORY OF THE PETRIFACTION OF WOOD PROPOSED....PETRIFIED WOOD, SILICEOUS, CALCAREOUS, AND ALUMINOUS.

Whilst endeavouring to ascertain the nature of the processes, by which the several bituminous substances have been formed, it was suggested, that the ligneous parts of vegetables, in detached pieces, as well as in large masses, when placed in subterranean situations, and pervaded by moisture, pass through certain spontaneous changes, from the intestine motion of their particles, and the new arrangement of their principles, by which they gradually acquire a bituminous nature. In this manner is formed bituminous wood; which, if the process is not interrupted, it is presumed, passes into the state of pure bitumen; or if exposed to the influence of certain circumstances, already particularised, a different modification of its particles ensues; and jet, or some of the different varieties of coal, are produced. But if the superincumbent strata be not sufficiently compact, to confine the more volatile matters; if the water be in too large, or in too small a quantity, or not sufficiently stagnant; or if any other circumstance prevent the farther progress of the bituminous fermentation—the bituminous wood, being now rendered unfit for the food of insects, and having acquired a considerable degree of durability, may remain without any farther change for ages. This fact is rendered evident in many parts of this kingdom, where trees have been thus preserved from a period beyond the tradition of man.

In this bituminized wood, two circumstances are observable, which are particularly deserving notice. The first is, that, although rendered essentially different in its nature, it frequently happens, that its form has undergone no change, and that the disposition of its fibres has suffered hardly any alteration. The second is, that, when found in wet situations, its substance is so thoroughly pervaded by water, that it may be discharged from it as from a sponge.

Reflection on these circumstances must shew, that this wood is in the exact state which fits it, for becoming a similar substance, with that which most specimens of fossil wood present to our view. The form and structure of the wood, with even some of its smaller fibres, are curiously preserved; water pervades every part of it; and its durability is such, as to ensure its preservation until that event happens, on which its consolidation appears to depend—the saturation of the water, with which it is in every part imbued, with earthy particles, chiefly in a state of solution. These consolidating, by the formation of extremely minute crystallizations, through the whole softened mass of bituminized wood, gives it an aluminous, a calcareous, or a siliceous substance, without disturbing the existing arrangement of its fibres. Thus appear to be formed all those fossils, which really deserve the name of petrifactions: and thus, perhaps, can, alone, be explained that curious phenomenon—the exact preservation of even the minute fibres of the wood; still retaining their continuity, and their original characteristic disposition, whilst their substance has undergone a conversion into stone.

Thus, I trust, may the petrifaction of, by far the greater part of, vegetable fossils be explained. The several species, and varieties, dependent on the different substances which have been thus changed; on the kind of earth, and on the state in which the particles of earth have been deposited, will necessarily be the subjects of separate examinations. For although, in almost every case, of vegetable petrifaction, the earthy particles appear to have been deposited chiefly in a crystalline form, it is not meant to deny, that this process may have been aided by the introduction, and deposition, of those fine earthy particles, which have been merely suspended in the water. On the contrary, in, by far, the greater number of instances of vegetable petrifactions, the combination of both operations is easily discoverable.

In thus endeavouring to account for the formation of most of the endless variety of vegetable petrifactions; which, from the wonderful appearances they display, and the circumstances under which they are found, are considered as, almost, anomalies in nature, I am aware, that the theory proposed, respecting the formation of bitumens, will be exposed to a severe test: tried by such a touchstone, the degree of estimation to which it is entitled, can hardly fail of being ascertained.

Although convinced of almost the universal agency of bituminization, on such vegetable substances as have been rendered subjects of the mineral kingdom, yet it does not appear to be the sole process, by which vegetable matters may have been preserved from total decay, a sufficient length of time, to admit of their slow impregnation with lapideous or metallic substances. The ligneous substance we have already seen, is of so indestructible a nature, as to secure its long continuance, in various situations, without undergoing any material change of appearance; even after the other constituent parts of the wood have been removed. This appears to be the state in which light rotten wood, or touch-wood, exists: all the constituent parts, excepting the ligneous substance, having been removed, either by the long continued action of the air, or by some morbid action of the vessels of the wood. If this species of wood, therefore, be placed in situations, in which water holding earth in solution can permeate it, there exists but little doubt that it may become petrified. Another mode by which the mineralization of vegetables may be secured, appears to be, that of decaying, but comparatively, recent vegetables, becoming impregnated by some saline, metallic solution, of iron, for instance, whilst a precipitated oxide of the metal fills up the interstices, and involves the whole in a confused mass; as may be seen in the bog-iron of Shropshire, and many other parts.

But, even admitting these instances of variation, I trust you will perceive, that the grand agent in the mineralization of vegetables, is the process of bituminization; which readily melts down the ligneous substance—that substance which yields to hardly any other process, natural or artificial, and which resists almost every power, but that of fire. The examination of the vast variety which vegetable fossils yield, and the attempt to explain the circumstances, on which their different appearances depend, will best serve to shew the degree of solidity which this theory possesses, which thus supposes the process of bituminization, to be the basis, as it were, of the petrifactive process by which the greater part of vegetable fossils have been formed.

The earths which are most frequently found to be the chief constituents of vegetable fossils are silex, lime, and alumine; and, according to the preponderance of either of these earths, may the fossil be distinguished by the term siliceous, calcareous, or aluminous. Unwilling to take liberties with the mode of expression which common usage has authorized, unless able to demonstrate a positive superiority, in the mode which is proposed to supersede that which is already adopted, I will not urge the adoption of such expressions, as pyritified wood, silicified wood, &c. which point out the circumstance, of the substance having been once wood, but having now assumed an entirely different nature. I cannot, however, omit to observe here, that such words as do imply a real transmutation, may frequently be employed, without meriting that degree of censure, which we have already seen is bestowed on them, by M. Daubenton; since, although the stony nature of such substances is admitted to be merely the result of an earthy impregnation, the substances thus impregnated will, I believe, in general, be found to have suffered an actual transmutation—a total change in its nature; that which was ligneous having at least become bituminous.

As the fossil wood, which appears to exist most abundantly, is that which has undergone a siliceous impregnation, and as the formation of this species of fossil wood appears to be the most difficult to be explained, we will take it first into consideration. But as its impregnation is here assumed to have been accomplished by a solution of the silex, in some aqueous menstruum; a circumstance of which no positive proof can, perhaps, be adduced; it is necessary, previous to entering into a particular examination of this substance itself, to determine what degree of force is possessed, by that collateral evidence, to which we are necessitated to have recourse.

So regularly does the earthy matter appear to have been diffused, through every part of the changed wood; and so intimate is the union which has taken place, that its deposition from an aqueous menstruum, in which it had been held, either in a state of suspension, or of solution, appears to be obvious. That it has chiefly been deposited in minute crystallizations, which by their regular apposition to each other have, at length, formed that continued siliceous substance, of which these fossils are in general composed, may be almost generally inferred, from the circumstance, of most of these specimens having their surface invested with a crust of extremely minute crystals; and from a similar investiture, even, surrounding, in some specimens, every distinct *compages* of fibres, and lining the sides of every cavity, without obliterating them; whilst, in other specimens, similar cavities, and fissures, proceeding from a deficiency of woody, or bituminous matter, are filled with a transparent quartzous mass. These circumstances are so plainly indicative of a slow deposition, from a solution in some aqueous menstruum, that here we might have rested our belief; if it had not been asserted, that all these effects might have been produced, by the injection of silex, rendered fluid, *by simple fusion*, *by heat*. This renders it, therefore, necessary, that we should first endeavour to ascertain, whether corresponding impregnations of other substances with silex, are attributable to the influence of water, or of fire.

Yours, &c.

LETTER XXXII.

SILICEOUS PEBBLES....CONJECTURES AS TO THE TIME, AND MODE OF THEIR FORMATION....CRYSTALLINE FLUID OF REAUMUR.... AGATINE NODULES....THEORY OF THEIR FORMATION....OPINIONS OF DR. HUTTON AND MR. PLAYFAIR....AQUEOUS ORIGIN SUPPORTED.

THERE is hardly any one of the combinations into which silex enters, but displays some phenomenon to our admiration. The sand and pebbles which we tread upon, and which so seldom attract the attention, are fraught with mystery. Henckel, with mingled perplexity, and wonder, exclaimed, " O Caillou! Caillou! qui est ce qui t'a engendu? Est ce donc qu'il ne seroit possible de se faire quelque idée de la manière que cette formation se fait?"

Almost without a hope of adding to what is already known, respecting these substances, I shall lay before you a few words concerning the formation of siliceous pebbles; hoping, that I shall thereby, however, make some advancement in a knowledge of the circumstances, on which the siliceous impregnations of wood depend.

Various opinions have been entertained as to the æra of the formation of pebbles: some believing their existence to be coeval with the creation; others supposing them to have obtained their present forms at the reformation of the world, after the deluge; whilst others conjecture, that their formation is going on at the present day. That many of them have been formed, at periods later than the creation of the world, is rendered indisputable, by the various impressions of organised substances which they bear. The strongest evidence which has been adduced as to their more recent formation, is that of Dr. G. Gardner, of Aberdeen, contained in a paper published in the Philosophical Transactions*; he relates, that, " upon the river Don, a little below the bridge, upon the river's mouth, there is a bank, the face of which is broken down; and it is full of stones, which one would think were *in fieri;* they are all either round or oval, of different sizes; the faces of most of them are broken off, they are soft, and will easily rub down with your hand; they are of different grits and colours, and are made up of different sands and clays mingled together; the clay is soft, both to the hand and taste; in some of them, white, in others, grey, though, in some places, the clay and sand are hardened to a very considerable degree." Dr. Gardner proceeds to remark, that they bore a very near resemblance to such oval stones, as we see in the fields; and that where they were softest, the bed which each stone laid in, was always hard, and of another grit and colour. It is impossible to read this account without suspecting, that siliceous pebbles, in general, may have had an origin, somewhat similar to this. The pebbles of which the pudding-stone is chiefly formed, generally yield such an appearance, as may be supposed to have been the effect of pressure, whilst they existed in a soft state; and we have a curious instance, related by the celebrated Bergman, illustrative of this circumstance—a mountain of pudding-stone, in the lower strata of which, the pebbles shewed evident marks of having suffered compression; being reduced to little more than the thickness of half-a-crown. Little margaceous nodules, the mineral bezoars of some, composed of various laminæ of soft earth, of different colours, may be frequently found in the gravel-pits in England, and in large heaps in several parts of Italy; appearing to differ from siliceous pebbles, only in not having been impregnated with siliceous matter. That such an aggregation of particles of clay and sand, as may form a fit substratum of pebbles, may even now take place, and that these bodies may attain the forms of pebbles by attrition and the action of water, is very probable. In what manner that process, on which their induration depends, is accomplished, is not, however, easy to ascertain.

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* Philosophical Transactions, Vol. XV. N° 175.

The opinion of Mons. Reaumur, as to the manner in which this part of the operation, in the formation of pebbles, is accomplished, appears to be not only perfectly consonant with the appearances which pebbles yield; but also with those which are yielded by the several siliceous petrifactions, which are more particularly the object of our inquiry*. He remarks, that, by a coarse operation, emery is reduced to powder, and suspended in water, for several days; but, he observes, Nature may go much further; for the particles which water detaches from hard stones, by simple attrition, are of an almost inconceivable degree of fineness. Water, thus impreg-

* Memoires de l'Academie des Sciences, &c. 1721, p. 251.

nated, he supposes, contributes to the formation of pebbles, by petrifying of stone, as it were, a second time: stones, already formed, but remaining of a spongy nature, acquiring a flinty hardness by an impregnation with this crystalline fluid. Thus impregnated, masses of different clays, chalks, marles, and boles, become flinty stones: and thus, he remarks, this crystalline fluid, filtering through a porous lime-stone, will deposit its very minute particles, in all the interstices, existing between the particles of the stone, which at last they will quite close up. All the spaces between its molecules being thus filled with siliceous matter, which serves to agglutinate the molecules in a compact mass, the stone, he concludes, will possess a flinty hardness; and will exhibit nothing of a granular appearance in its fracture.

From such an impregnation of masses of various earthy matters proceed basaltes, Egyptian pebble, various coloured jaspers, agates, &c. and by such an introduction of siliceous matter, in aqueous solution, or in a state of extreme division, into moderately soft and rounded nodules, of different combinations of the earths, variously coloured by metallic oxides, and chiefly by those of iron, are formed those pebbles, whose external coat, differing from their internal substance, distinguish them from the small boulders of porphyry, jasper, agate, cornelian, marble, lime-stone, &c. which, detached from the rocks, and forcibly agitated by the waters of the sea, become rounded by attrition against each other.

In the present advanced state of chemistry, it is unnecessary to dwell on the opinion which has been entertained by M. Patrin, M. de Carosi, and others, that chalk undergoes a conversion into flint, except for the sake of remarking, that all those apparent transmutations, which have given rise to this opinion, are easily explained, by supposing a partial introduction of a siliceous fluid, in various quantities, into porous calcareous earth.

The numerous impressions of organic substances, such as shells, coralloids, spines of echini, &c. discoverable in the substance, and on the surface, of pebbles, prove these to have existed in a soft state; and render it probable, that these bodies became involved in them, whilst the pebbles, yet forming, were gently moved about among the exuviæ of marine animals at the bottom of the water. By the concentric line observable in many pebbles, the accumulation of successive coats, whilst in a soft state, is sufficiently proved. The various plum-pudding stones clearly point out the infiltration of a siliceous fluid, which has perfectly cemented together the several pebbles, which had before been connected, by interposed particles of sand, clay, &c.

Frequently the external surface, or coat, of the pebble, will be formed by a hard siliceous crust; a small part of which being removed, shews that the remaining substance of the pebble is a soft, pulverulent, sometimes argillaceous, and sometimes calcareous, matter. In this instance it appears that the siliceous matter has introduced itself only to a certain depth in the substance of the pebble; the rapidity of concretion, or crystallization, having prevented any subsequent introduction of the fluid. A pebble, now before me, seems plainly to shew, that the process, by which the induration of these pebbles is accomplished, is not suddenly performed. A part of this pebble is covered with a crust similar to that with which these pebbles are commonly invested, which terminates by a strong defined ridge, within which is a substance, the appearance of which plainly marks it to have been the soft internal substance, which had been deprived of its crust, previous to the thorough penetration of the siliceous matter. In this are stuck about twelve small black siliceous fragments, which, by a subsequent infiltration of siliceous liquor, are now firmly connected in one solid mass, with the originally soft internal substance of the pebble, a depression existing in one part, formed by one of these fragments, which has since separated.

Organic remains, which originally contained a considerable proportion of calcareous earth, are frequently found imbedded, or inveloped, in these pebbles; and are often so thoroughly pervaded, in some parts, by the siliceous impregnation, as to be absolutely siliceous; but, sometimes, the calcareous earth is, in other parts of the same stone, still so predominant, and is united with so much carbonic acid, as to effervesce strongly on the application of even vinegar. Strong evidence of the slow accretion, and of long continued application of the indurating matter, in a state of solution, to these pebbles, during, and even subsequent, to their having assumed the general form which they now possess, may be found in a variety of the siliceous pebble, which appears to have derived its shape from an organic body, apparently a species of coral, which it has invested. In this pebble, the holes are frequently left, through which some parts of the contained body have projected. But frequently it will also be found, that these holes are filled up, in various degrees, by siliceous matter, shewing the strongest marks of its apposition, from an aqueous solution, subsequent to the formation of the stone: sometimes it surrounds and penetrates the extraneous body itself, and at other times fills up the hole so exactly as to leave externally only a circular seam; not much differing from the appearance of a cicatrix. Another proof of the subsequent addition of siliceous matter, in solution, to pebbles, offers itself in the junction of the fractured parts of the boulders of sand-stones, for instance, by the interposition of siliceous matter; thus, frequently, will the fragments be seen to be united by a very minute seam: not such as might be supposed to have originally existed in the rock of which this stone is a boulder; but a slight crack passing through its substance, and which yields to different degrees of force in different pebbles, according to the various degrees of agglutination it has experienced. Having laid before you some of the circumstances which the pebbles, forming the vast beds of gravel so frequent in this island, offer in proof of the influence of water in the process of siliceous impregnation, it becomes necessary, in the next place, to determine, whether agates, and agatine nodules, derive their formation from the influence of the same agent; since it has been eagerly contended, by Dr. Hutton and Mr. Playfair, that their formation depends on the injection, in a state of fusion by heat, and subsequent cooling, of siliceous matter. This examination is rendered the more necessary, by the latter gentleman's considering it to be impossible, that the igneous origin of fossils could be recorded in plainer language, than by the phenomenon displayed in the formation of the agate. Concluding, as every appearance, indeed, warrants, that the progress of consolidation, both in the solid and hollow agates, has been from the circumference inwards, he says, "Now it must be considered that these coats are highly consolidated; that they are of very pure siliceous matter, and are utterly impervious to every substance which we know of, except light and heat. It is plain, therefore, that whatever, at any time, during the progress of consolidation, was contained within the coats already formed, must have remained there as long as the agate was entire, without the least probability of escape. But nothing is found within the coats of the agate, save its own substance; therefore no extraneous substance, that is to say, no solvent, was ever included within them. The fluidity of the agate was therefore simple, and unassisted by any menstruum. In this argument, nothing appears to me wanting, that is necessary to the perfection of a physical, I had almost said of a mathematical demonstration*."

To determine the degree of force with which this argument opposes the opinion, that these, and similar bodies, have originated from a solution of silex, in an aqueous menstruum, will, I trust, be best done, by endeavouring to point out those which appear to be the most probable modes, in which these bodies may have been formed.

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* Illustrations of the Huttonian Theory, p. 79.

Siliceous and agatine nodules have, either their whole substance formed by a solid siliceous mass, or the siliceous matter is confined to a crust, varying in its thickness. This latter kind is termed a *geode*, and is either hollow and empty, or contains substances different from the crust itself, such as sand, indurated clay, and even water. If a loose hard stone is contained, within a stone thus formed of a siliceous crust, it forms the stone named by the ancients *Ætites*, from its being supposed to be frequently found in the nests of eagles; the contained stone being termed the *callimus*. If the crust is empty, or contains loose sand, or other earthy substances, or is filled by any other kind of earth, it is termed simply a *geode:* but if it contains water, it is then distinguished by the name *enhydros*.

It cannot have escaped your observation, that the absence of water from the interior of these siliceous nodules is a circumstance, on which Mr. Playfair chiefly founds his hypothesis; but the fact really is, that water is very frequently found in these nodules; and that the stone, thus termed *enhydros*, is very frequently mentioned by lithologists. The German mineralogists speak of them in such a manner, as by no means to imply their being of rare occurrence. In Germany, indeed, from the abundance in which siliceous and agatine nodules there exist, they might be expected to be met with: but even in our own country they are also frequently seen. They are found, I am informed, in and about the neighbourhood of St. Vincent's rock, near Bristol; and in no crystalline geode, which I have seen from St. Vincent's rock, is there a single circumstance to lead to a doubt as to their having contained an aqueous fluid. Dr. Plot, in his History of Staffordshire, relates, that among the best sort of iron-stones, called *mush*, are frequently found round, or oval, blackish and reddish stones, sometimes as big as the crown of one's hat, hollow, and like a honey-comb within, and holding a pint of sweet liquor; which, according to the colour of the comb within (whatever the stone be without) is either red or white; and, whether the one, or the other, of a sweet sharp taste, very cold and cutting, yet greedily drank by the workmen. It is especially found in that sort of mine, the country people call the *white mine*, which yields the best iron-stone, where the workmen commonly, upon breaking a stone, find it inclosed in the centre, sometimes to the quantity of a *hogshead*, in one cavity, of a sweetish taste, but accompanied with a vitriolic, or iron-like twang*.

Dr. Woodward, speaking of some specimens of enhydri, says†, "they were found, amongst many others, in sinking the wells in *Caen-Wood*, whence that water, which we call the *Hampstead* water, is derived.—I was down only in one of the wells, which they were then in digging; but I saw several of these enhydri, with a pretty many pyrites, amongst the earth that was flung forth of the other wells. They are of several sizes, from the bigness of a walnut, to about two feet in breadth. They are generally of a compressed shape; and lessen, or grow thinner, towards the edge, or *ambitus*, of them. Those that I saw, lay about fifteen or sixteen feet deep, in a stratum of sandy clay. The surfaces of that stratum, and the flats or larger plains of the enhydri, lay parallel and level: they were all hollow, and usually divided into several cells; but these were uncertain, in their number, figure, and capacity. The partitions of the cells were rarely very thick. The outer coat was in some double, in others triple, and in a few quadruple; as consisting of two, three, or four strong crusts, involving and carrying one another. The cavities or cells were generally near full of an insipid coagulum, or liquor, about the consistence of cream, though in here and there one, it was a little thicker. 'Twas most commonly of a greyish colour; but in some few 'twas of a bluish, and in others of a blackish hue."

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* The Natural History of Staffordshire, by Robt. Plot, LL. D. 1686.

† An Attempt towards a Natural History of the Fossils of England, by J. Woodward, M.D.

Whether it be believed, that these several bodies owe their existence to fire or water, it will, I conceive, be equally admitted, that they have been formed in cavities, previously existing in the matrix, in which they are contained. I suppose, then, that one of these cavities becomes filled, by some small aperture, with a liquid holding silex in solution; that siliceous crystals form all round the cavity, except at the aperture, where there is nothing to attach themselves to; and that an aperture in some other part allows a regular escape of the fluid, by which a correspondent supply is demanded from the first-mentioned aperture, until, after, perhaps, the lapse of ages, the crystals fill up, from the bottom and sides, to the aperture by which the fluid was admitted, and form a solid crystallized mass, from which the water is excluded. Nor does it even appear necessary, for the formation of a solid crystalline mass, that there should be more than one opening, that which admits the fluid into the cavity; since the calibre of the opening bearing a proper proportion to the cavity to be filled, it will remain open until the mass of crystallization is completed; it being reasonable to suppose, that the fluid containing the silex would, in consequence of its superior gravity, be continually supplying the place of that, which, having been deprived of its silex, by crystallization, would of course tend upwards; and thus might the cavity become entirely filled by crystallization, to the total exclusion of the solvent. The sections of agatine nodules indeed shew complete and uninterrupted concentric coats, without any such departure from the circular form as would point out the opening by which the cavity had been filled; but then it is to be considered, that it is only in one particular direction, that this could be shewn, in a section; in every other direction the concentric coats will appear perfect and regular. But when the laws on which crystallization depends are considered—it being a process in which the suspended molecules are united together, by their particular attractive forces, according to certain laws regulating their aggregation, and directing the forms which they assume, *to the exclusion of water*, except so much as enters into chemical union in their crystals—surely it is not contrary to reason to suppose, that a cavity may thus be filled by crystallization, to the total exclusion of the solvent. Thus, then, I conceive, *solid agatine and other siliceous nodules* may have been formed, to the entire exclusion of the solvent.

But this assumed process being even allowed, it must be admitted, that the following variations of it must be liable to occur. The aperture, by which the cavity is supplied, may be closed by the crystals at its sides meeting, previously to the filling of the cavity by crystallizations: or, instead of the liquid being admitted by one aperture, it may percolate through numerous small openings into the cavity. It is therefore necessary to see how the process will be affected by these variations.

The aperture may become closed, under two circumstances: there may, or there may not, exist some small fissure, or pores, by which the fluid remaining in the cavity, after the supply has failed, may drain off. If the former be the case, the *hollow, empty, crystalline nodule* remains; and if the latter, the water is inclosed, and the *enhydros*, so often mentioned by lithologists, is formed.

It now remains to inquire, what would be the consequence of the fluid infiltrating, through the substance forming the top and sides of the cavity, instead of entering by one aperture only. Here, as in the other instances, condensation would commence at the circumference, or sides of the cavity; but would go on so slowly, as to admit the farther infiltration of the fluid, for a considerable time; and the same porosity of the substance forming the bottom of the mass, would likewise allow the gradual exit of the superfluous fluid.

The process which is thus carried on, in this small cavity, will be found to agree, almost in every respect, with that, which we shall soon see has taken place, in caverns adorned with calcareous stalactites. As in those, so the surrounding substance of these smaller cavities differs, in closeness of texture, in different parts; opposing more resistance to the infiltration of the fluid, in some parts than in others: hence the fluid oozes in a partial and irregular manner, according to the resistance it meets with. In some parts, where the adherence of the particles is loosest, the fluid, loaded with suspended earthy particles, slowly collects, drop after drop, and deposits its earthy matter in a stalactitic form; whilst, from those parts, where the resistance to the admission of the fluid is greater, the more closely filtrated fluid deposits only a coat of drusy crystals. The examination of a polished section of one of these crystalline geodes shews the opaque crust, in the closest continuity with the transparent siliceous mass; the crust being more opaque, as it extends to the circumference, and the internal crystals acquiring a state of pellucidness, as they reach towards the centre. A similar gradual departure from opacity to clearness, effected much in the same manner, may be observed in the familiar instance of the crystallized mass, which sometimes forms on the external surface of a flannel strainer, which has been employed for the filtration of a saturated saline solution. This circumstance is particularly observable in the *fossil fruits of Mount Carmel*, of which we shall have again to speak more fully: the external substance of these is generally of a light fawn colour, marked in some parts by a dark ochrous tinge; but the more internal part is white, and is generally completely transparent toward the centre. These bodies also, almost always, contain the above described internal stalactiform projections, which are covered by a drusy crystallization. In these crystalline, as well as in the other geodes, water is frequently found, forming another species of the *enhydres*; and, where it has not been found, very minute, and almost imperceptible, fissures or pores, may, during a long space of time, have allowed the liquid gradually to escape. A careful examination of these crystalline and agatine nodules, and long reflection on the circumstances, probably dependent on their formation, oblige me, in opposition to the opinions of Dr. Hutton, and of Mr. Playfair, to believe, and almost to assert, that they must have derived their origin, from siliceous matter in a crystalline form, deposited from its solution, in a fluid menstruum, filtrating into cavities, previously existing in the bed, in which these bodies have been formed.

Whilst endeavouring to trace the operations of nature in these processes, imagination, it must be acknowledged, has sometimes prompted the judgment; but for this, I trust, I shall obtain an excuse from you, as well as from Mr. Playfair. In inquiries, respecting operations performed in very distant ages, and where the materials from which our information is to be derived, are really so few, and so unconnected; being snatched, either from the wrecks of a deluge, or the ashes of a conflagration, imagination must, if ever, be allowed to lend its aid, in the inquiries of science.

Yours, &c.

LETTER XXXIII.

SILICEOUS WATERS OF CARLSBAD....OF ICELAND....OF BATH....SILICEOUS TUFA OF THE GEYSER....VEGETABLE CALCULI....FLINT IN THE EPIDERMIS OF PLANTS.

Seeing reason to conclude, from this circumstantial evidence, that the siliceous matter deposited in secondary fossils, as well as in pebbles, &c. has been held in solution, in some aqueous menstruum, it next becomes necessary to inquire, by what solvent this solution has been accomplished.

Subsequent observations have shewn, that the opinion of Mr. Reaumur, in favour of the agency of a siliceous fluid, is established on a much firmer foundation, than was for a long time supposed. The celebrated Bergman first determined the solubility of silex in simple water; and demonstrated its existence, in a state of solution, in the Geyser, and other boiling springs of Iceland. Mr. Klaproth, in the year 1789, first ascertained the existence of siliceous earth in the boiling mineral waters of Carlsbad, in Bohemia; his experiments proving, that in 1000 cubic inches of the main spring, 25 grains of silex were contained, in a state of actual solution. The quantity of silex contained in the water of the Geyser, is even in a much larger proportion, than that which is found in the waters at Carlsbad. Mr. Klaproth found, on subjecting the water of the boiling spring at Rykum, in Iceland, to his analysis, that a hundred cubic inches of it contained,

	Gr.
Carbonate of soda	3
Sulphate of soda	5
Muriate of soda	8.50
Siliceous earth	9
	25.50

Being the powder left after evaporation.

Dr. Gibbes has discovered*, that 10 pints and a half of the Bath waters contain about 20 grains of silex, being in the proportion of about 15 grains and a quarter to the gallon. This discovery of silex, where it was not expected, is shewn, by Dr. Saunders, in his excellent Treatise on Mineral Waters, to be of great importance, in explaining some apparent errors in former calculations respecting these waters.

Bergman had, at the first, accounted for the presence of silex, in a state of solution, in such waters, to the natural solvent power of simple water, aided by heat; and this, he thought, was alone sufficient to account for this effect. Dr. Black, who made an analysis of the waters at Rykum, which very nearly agreed with that of Mr. Klaproth, thought that the alkali was the efficient cause of this solution of silex in water, and that the heat was merely the means of promoting it. But the quantity of pure soda contained in these waters is so small, when compared to that of the silex, as could not be sufficient to maintain the solution of the latter. To obviate this difficulty, Dr. Black suggested, that the silex had originally been united with a much larger portion of alkali; and that, after this solution had been completed, part of the alkali might have become neutralized by acids, which had entered into combination with the fluid. But, to effect the solution of the silex by the means of the alkali, the alkali should exist in a pure, or caustic state, of which not the least proof has been adduced; besides, as it is now rendered evident, that water alone possesses the power of dissolving silex, it is entirely unnecessary to seek for the aid of an alkali. The great degree of heat of these waters may, however, be considered as promoting their solvent powers; since, according to the relation given by Uno Von Troil, in his account of the Icelandic springs, the waters of the Geyser, thrown by this immense jet of 19 feet in diameter, to the height of 90 feet, are still found, when they fall to the ground, perfectly boiling hot. As part of the heat must have been lost during the spouting, consequently the water must have been some degrees hotter, in the subterranean reservoirs. Thus, Mr. Klaproth observes, Nature here affords us an instance, in the large way, of what Art performs in the small, by Papin's digester; namely, of confined water, even while in its unelastic, dense, liquid state, acquiring a degree of heat, surpassing that of its boiling point. But, notwithstanding he admits the power in heat, of promoting the solution; yet he remarks, that experience has shewn, that an actual solution of silex in simple water takes place, not only in springs, the natural temperature of which is much inferior to the ebullient heat of those in Iceland, but also in several other mineral waters: and even that some common sweet-water springs contain dissolved siliceous earth.

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* Nicholson's Journal, vol. iii. p. 403.

In corroboration of the opinion, that the induration of various substances may have been derived from the deposition of siliceous matter, from its solution in water, I must call your attention to the siliceous *tufa* which is deposited by the Icelandic hot-springs; in the same manner as the calcareous *tufa* is deposited by mineral springs impregnated with lime, as in those of Matlock. A bason of 60 feet in diameter, the outer border of which is 9 feet above the opening of the pipe, as well as the pipe itself, which is 19 feet in diameter, and which, from its depth being unknown, is considered by the Icelanders as the *gate of hell*, are entirely formed by deposition from the boiling water of the *Geyser*, which is sometimes thrown out, from this enormous opening, to above the height of 100 feet. This tufa having been analysed by Mr. Klaproth, was found to consist of,

	Gr.
Silex	98
Alumine	1.50
Oxide of iron	0.50
	100[*]

M. Gensanne relates, that in the mines of Cramaillot, in Franche Compté, stalactitic concretions of silex form on the vaults of the works, from the transuding water; and that they are sometimes found on the timbers of the mine[†].

In addition to the proofs, already adduced, of the solubility of silex in water, we may notice the circumstance of its having been found, in the proportion of 14 grains to 20 ounces, of the water collected in the cavities of basaltic columns. Its having circulated in the vessels of the animal body, and having been separated by the vessels of secretory organs; and thus forming, though rarely, a part of the human urinary calculus, may also be regarded as evidence of some weight. But its presence in different plants affords still more powerful proof of its solubility, since we cannot conceive its absorption, its transportation through the substance, and, lastly, its deposition in certain parts of plants, but in a state of actual solution in the water, with which the plant is nourished. Its presence in the ashes of plants is well known. Rumphius relates[‡], that in the island of Celebes, near Macassar, stones are frequently found, naturally formed in the wood, and fruits of different trees:

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[*] Analytical Essays, p. 408.

[†] Histoire de Languedoc, tom. ii. p. 28.

[‡] D'Amboinsche Rariteit-Kamer. III Bock. LXVIII Hoofsdeel.

and that they are worn by the natives, being supposed by them to possess extraordinary powers; particularly that of defending them from the injuries of any weapon. These, however, will not, alone, afford us any considerable support; since, although the learned author describes them as *flint-like* stones, he mentions that they do not give sparks, and that they effervesce on being placed in an acid liquor. Mr. Macie has, however, found a pebble in the joint of a Bamboo cane, which was so hard as to allow it to cut glass*. Mr. Davy has ascertained, most clearly, that flint enters into the composition of the epidermis of bonnet-cane, and, indeed, of all cane of this kind. He found that when pieces of this kind of cane were rubbed together, strong sparks of white light were produced; and that, when forcibly struck together, the sparks were as vivid as those from a gun-lock. The cause of this was placed beyond all doubt, by his finding that 22 grains of the epidermis of the cane yielded 9 grains of silex. He also found it in English reeds and grasses, in oats, wheat, barley, &c. in a sufficient quantity to yield glass with the blow-pipe; a straw being thus converted into a fine globule of glass: the epidermis of the *equisetum hyemale*, or Dutch rush, appearing to consist almost entirely of silex†.

Presuming, therefore, that the siliceous induration of various substances will be allowed to have proceeded from a deposition of silex, from its solution in water, I shall, in my next, proceed to apply this principle, whilst endeavouring to account for the formation of silicized wood.

Yours, &c.

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* Philosophical Transactions, 1791, p. 385.

† Nicholson's Journal, May, 1799

LETTER XXXIV.

PETRIFIED WOOD....DIVIDED INTO SILICEOUS, CALCAREOUS, ALUMINOUS, &C.....SILICEOUS DIVIDED INTO SILICIZED WOOD AND SILICIZED BITUMINOUS WOOD....THE LATTER, INTO CALCEDONIC, AGATINE, JASPERINE, AND OPALINE.

For those substances which bear the marks of having originally existed as wood, but which now possess a stony hardness, from the introduction of different earthy matters, it seems proper to retain the term, which long usage sanctions, of PETRIFIED WOOD, *LITHOXYLON* of oryctologists. This may be divided into different classes, according to the predominance of the different earths with which it is impregnated: thus petrified wood may be subdivided into siliceous wood, calcareous wood, aluminous wood, &c.

The nature of these several kinds of wood we shall now proceed to examine, pointing out the different kinds *(genera)* into which each may be again subdivided, and the several species and varieties which demand particular observation. Fossil wood, which has been mineralized by an impregnation with silex, *HOLZSTEIN* of the Germans, and which we may term SILICEOUS FOSSIL WOOD, may be divided into two kinds. The first is that, in which the wood had suffered no real change in its nature, during its existence in a subterranean situation, previous to that produced by the siliceous impregnation. The second is that, in which bituminization had wrought its peculiar change on the wood, previous to its impregnation with siliceous matter. Of the former kind I know but one instance, and that of rather rare occurrence; which is, where the wood, previous to having been buried, had undergone that change, which we frequently see take place in the ligneous part of trees, and which reduces the wood to that state, in which it acquires the name of *rotten-wood.* The wood having been impregnated, whilst in this state, with silex, yields an appearance exactly resembling that of rotten-wood; but occasions no small surprise to any one who, taking such a specimen in his hand, expecting from its appearance to find it exceedingly light, discovers it to be possessed of considerable weight, from the great quantity of silex it contains. The specimen figured at Plate II. Fig. 1. is of this kind, it having the peculiar light appearance of rotten-wood, whilst its impregnation with silex has been to such a degree, as to have allowed it at one end to have assumed a very high polish, from the lapidary's wheel. Since this specimen has been engraved, I have obtained other specimens of this fossil wood, in which the loose and shivery texture of rotten-wood is still more decidedly manifest. This kind of fossil wood appears to be that to which the term of SILICEOUS WOOD may be most appropriately applied. The second kind of siliceous fossil wood is that which, previous to its impregnation with silex, had undergone the change which the bituminous fermentation induces: this kind of fossil wood may be termed SILICIZED BITUMINOUS WOOD; and its several species will be found to have depended much, for their general appearance, on the degree to which the bituminizating process had proceeded, in the wood, previous to its lapidefaction.

Bituminous wood, we have seen, may exist in two states: in one, the fibres, although rendered bituminous, and perhaps softer than in their original state, have not been so far changed as to run together and destroy the natural separation which exists between them. A specimen of bituminous wood in this state, dug up at Blackwall, is represented at Plate I. Fig. 1. In the other state, the bituminous fermentation appears to have proceeded so far, as to have occasioned such an approach to fluidity, in the bituminized wood, as to have allowed it to run together in a mass, by which the ligneous texture, and fibrous appearance have been lost. The Bovey-coal, of which we have already spoken, and which has been figured in Plate I. Fig. 3. is an example of bituminous wood, which has existed in this state. In specimens of this wood, its state of softness, nearly approaching to fluidity, may be inferred from the fibres, in one part of a specimen, being disposed in various distorted directions, very different from those which naturally belong to the woody fibre, whilst, in another part, they seem to have run together in one mass, in which every trace of fibrous texture is obliterated.

SILICIZED BITUMINOUS WOOD may, therefore, agreeable to these two different states, in which bituminous wood has existed, be divided into those species, in which the bituminizated fibres, having retained their solidity at the time of being impregnated with silex, have not allowed any diffusion of the matter, of which they were constituted, in the surrounding siliceous fluid, which merely penetrates and involves the bituminous fibres, and fills up all the interstices, without being itself affected by the bitumen; and into those, in which the bituminous mass has been in so fluid a state, as to allow its intimate mixture and union, with the permeating lapidific fluid, which thereby assumes, with other peculiar properties, a lustre similar to what might be expected, from a mixture of silex and of bitumen. The species which seem to have depended on the first of these states for their present mode of existence, are, 1st, CALCEDONIC FOSSIL WOOD; 2dly, AGATIZED; and, 3dly, JASPERINE; whilst all the numerous specimens, whose modification has depended on the second of these states, may be considered as belonging to OPALINE FOSSIL WOOD. These several species we will now proceed to notice, in the order here observed.

Yours, &c.

LETTER XXXV.

CALCEDONIC WOOD....AGATINE....JASPERIZED.

Calcedonic fossil wood appears to be the most simple form, in which silicized bituminous wood is found to exist; and, therefore, serves to shew, most clearly, the nature of the impregnation of solid bituminous wood with a solution of flint. In this wood, the colour and general appearance of which manifests very plainly its previous bituminization, the siliceous impregnation, in those specimens which I possess, has been such as to have given to them sufficient hardness to dispose to the conchoidal fracture, approaching in some parts to the shivery; and to occasion them to yield sparks, by percussion with steel. Their external surface has the whiteness of wood which has been long exposed to the air; but a section of them shews the internal substance to be of the colour of dark brown bituminized wood. The characteristic difference of this species of fossil wood is, that, although the siliceous fluid has pervaded every part of it, it has entered into no other union with it, than that of penetrating every fibre, and filling up every minute interstice, without dissolving any part of the bitumen, or even entering into such chemical union with it, as to allow it to manifest the least trace of bitumen, in its lustre, transparency, or colour, in any of those parts where the silex has been allowed to transude, and separate from the general mass of the impregnated wood: the siliceous matter assuming, generally, in those situations, the mammillated surface, and that degree of transparency, which is in general displayed by siliceous matter, in that form which is termed mammillated calcedony. In Pl. II. Fig. 10. is represented a specimen, shewing the whitened surface, beautifully invested with transparent mammillated calcedony, appearing as if it had percolated through the substance, and had coagulated on the surface of the wood. Plate VIII. Fig. 9. represents another specimen, in which the circular cavities, which had been formed by the *teredo marina*, are filled up by the transudation of the uncoloured, pellucid calcedony. At Plate II. Fig. 11. a specimen is depicted, which appears to have suffered a higher degree of bituminization, in consequence of which the filtered siliceous matter, with which it is every where beset, in the form of yellow semi-pellucid globules, appears to have derived some slight tinge from the bitumen; which, in consequence of the more perfect state of bituminization, in which it had existed, may be presumed to have been in a more fluid state, than the bituminous wood which had helped to constitute the two before-mentioned specimens. Specimens of this kind of fossil wood are, I believe, rather rare; but the separation of siliceous matter, with which solid bituminous wood has been saturated, may be very frequently seen in specimens, in which the whole silicized bituminous substance is covered with resplendent drusy quartz crystals. Instances of this kind are so numerous, as to render an illustration of this appearance, by a Figure, unnecessary.

AGATINE fossil wood. This term may be appropriated to such fossil wood as possesses a glassy lustre, breaks with rather a conchoidal fracture, gives sparks freely with steel, and is either marked by spots and illinitions of a bright crystalline matter, with which its vacuities have been filled, or has its several surfaces and cavities lined with quartz crystals. The blending of the characters of agate, and of fossil wood, seems to have been generally effected, by the accumulated investments of the drusy crystals, just mentioned, formed by the transudation of the clear siliceous fluid, into the interstices, and round the surface of the saturated bituminous wood. The substance and opacity of the altered wood will, however, getotally prevent that transparency, those fine marks, and those other appearances, which generally characterise the modifications of silex to which the term agate is given. In one specimen, however, now before me, such appears to have been the tenuity and the smallness of quantity of the bituminous wood, as to have allowed the siliceous matter, with which it is involved, to possess a considerable degree of transparency: and in the specimen depicted at Pl. VIII. Fig. 3. and 5. of the starry stone of Chemnitz, the tubuli are filled with agatine matter, conspicuously displaying those marks, which characterize, what is termed, the fortification agate.

JASPERIZED wood is never itself transparent, nor has any crystalline illinitions, except such as sometimes appear to have been produced by the filling up of little cracks in the stone, by a subsequent infiltration of a siliceous fluid. Its fracture is conchoidal, very rarely splintery; its lustre is dull, and its hardness varies with its proportion of silex. The general characters and properties are such, as readily lead to a knowledge of the nature of its composition. The veined or cloudy appearance of these stones may, in general, be very easily traced to the introduction of fine earthy particles, between the detached masses of bituminized fibres of the fossil wood, which have been all consolidated together by a subsequent infiltration of a solution of silex. The specimen, of which the polished section is figured at Pl. II. Fig. 8. will serve to point out how much this opinion is favoured by the appearances yielded by this species of wood. The examination of jaspers has shewn that they generally contain silex and alumine, and even other earths, in different proportions; whilst the following essays corroborate the idea of bituminous matter entering, in a small proportion, into the composition of this species of fossil wood.

Sixty grains of jasperized wood, reduced to powder, were mixed with double the quantity of purified pot-ash, purified by Mr. Allen, to which was added a sufficient quantity of distilled water, to dissolve the pot-ash. The powder which settled, and which was nearly white when dry, but became darker on being wetted, in about four or five days, shewed a line of darker matter on the surface of the precipitate; which, during a month, continued to increase, when it seemed to constitute, *in bulk*, about one fourth of the whole precipitate. Half this precipitate, added to colourless sulphuric acid, evidently darkened it: but willing to avail myself of the kindness of my friend Mr. W. H. Pepys, whose well-known abilities would stamp unquestionable authority, on the results of his experiments, I requested that gentleman to subject the remainder to an examination, for the purpose of ascertaining the presence of carbon. According to his obliging communication—the separated precipitate, after having been washed with distilled water, and dried at 212° Wedgwood, weighed 1.3 grain. Upon projecting a small portion in colourless sulphuric acid, nearly boiling, sulphureous gas was evolved, and the acid slightly blackened. Upon projection of another portion in boiling nitrate of pot-ash, gas was liberated, without sparks, or scintillation. There are undoubtedly, Mr. Pepys remarks, difficulties in ascertaining from what source the carbon may have been derived; the purest, and most caustic, alkali obtaining carbon in its treatment with alcohol, which mechanical means alone have yet been able to separate. Willing to obtain some more information with respect to these volatile matters, which might have escaped at 212° Wedgwood, I made the following experiment.

One hundred and eighty grains of jasperized wood, taken from a part where the ligneous form was most apparent, were placed in a glass retort, over the naked coals. When the bottom of the retort became red hot, a vapour became visible in its upper part, and its neck became discoloured by a light brown tinge, several small drops of water collecting in it at the same time. The bottom of the retort beginning now to run, the process was stopped. Upon examination, when the vessels were cold, the matter which had coloured the neck of the retort, appeared to be in too small a quantity, to determine its nature with any approach to precision. The water had very little taste: but both the retort and receiver yielded a very pungent, empyreumatic bituminous smell; which the latter retained for several days. This experiment, though imperfectly performed, seems to be sufficient to establish the fact, that some remains of bituminized vegetable matter were still present in the jasperized wood.

However great is the variety in which jasper is presented to our observation, there is hardly any appearance which it bears, which is not exactly borne by fossil wood. In one specimen of fossil wood, now before me, the fibrous texture of the wood is evident, whilst it at the same time displays all the characters of the *jaspis sanguinaris*, or blood-stone. Jasper, indeed, manifests so frequently the indubitable traces of wood, as to give room to believe that its origin has been derived much more often from vegetable composition, than has ever been supposed. It has often occurred to me to notice, in a specimen of polished jasper, appearances which, though striking, conveyed no idea of vegetable remains; but which obviously did so, after the judgment had been aided by the examination of another specimen, which, at the same time that it possessed the same general features, and characters, of the former specimen, manifested more plainly the marks of vegetable origin. Specimens of jasper, which excite no suspicion of their dependence on vegetable decomposition, in the minds of those unused to such inquiries; but which display indubitably such an origin, to those who have been in the habit of examining specimens of fossil wood, are very frequent; so frequent, indeed; and so much do I find, that observation extends the right of their claim to such an origin, that I can hardly help concluding, that most jaspers owe something, in their composition, to vegetable matter, changed by those processes, to which it was necessarily subjected after the universal deluge.

Yours, &c.

LETTER XXXVI.

OPALINE WOOD....THE RESULT OF THE UNION OF SILICEOUS AND SOFT BITUMINOUS MATTER.

We shall now proceed to the examination of that kind of siliceous wood, in which the influence, and, indeed, the presence, of bitumen appears to be indubitable.

Opaline wood, *Halbopal* of Emmerling, *Quartz-resinite xyloide* of Hauy, or silicized bituminous wood, is characterized by a peculiar waxy, or rather, resinous lustre. Its fracture is conchoidal, and generally shines with the particular lustre just described. Sometimes, the fibrous structure of the wood which remains will so direct the fracture, that the fragments will be linear, or laminated. Its specific gravity is from 2.045 to 2.675; and its hardness is such, that it will frequently yield sparks freely, on collision with steel.

In this, as well as the other kinds of petrified wood, we are astonished at discovering the nice state of preservation, in which the fibrous structure of the wood exists, whilst it has undergone so vast a change in the nature of its substance. This, it has been already remarked, appears to have been accomplished by the bituminization of the wood itself; by which process, although the disposition of the fibres is frequently not at all altered, its nature is changed; and it is rendered susceptible of an impregnation, with a fluid holding earth in solution.

The specimen depicted at Pl. II. Fig. 7. appears strongly to corroborate this opinion respecting the conversion of the ligneous into a bituminous substance, and its subsequent impregnation with siliceous particles. In that specimen is a knot of the wood, which differs, not in the least, in its appearance, from the knot in a piece of recent wood, but is perfectly impregnated with siliceous matter. Is it possible, that the change, which this knot has suffered, could have been effected, by an abstraction of the greater part, or, of the whole, of its original constituent parts, and a substitution of particles of a totally different nature? Its hardness, and its closeness of texture, must oppose an insuperable bar to the supposition; whilst the mysteriousness of the change is entirely dispelled, by admitting the operation of bituminization, and the consequent admission of siliceous matter.

But another circumstance, peculiar to this species of fossil wood, requires a particular inquiry: the result of which cannot but affect the opinion just noticed. This circumstance is the peculiar lustre which this species of wood displays: its fracture, in general, exactly resembles that of newly-broken resin; and, generally, the lustre of its external surface approaches, as near as possible, to that which would have been produced by pouring over it a thin coat of melted resin, or of fine varnish.

In the specimen of a petrified root, designed in Pl. II. Fig. 2. this kind of coating, thinly spread, covers and softens down all the asperities of its surface: and in Fig. 3. of the same Plate, the larger pores seem to have been diminished, and some of them obliterated, by the diffusion of this matter. The rough edge of the specimen, Fig. 4. of the same Plate, also derives a bright gloss from this seeming resinous varnish.

Struck by this appearance, the celebrated Hauy terms it, as we have seen, *quartz resinite xyloide*[*]; and Mr. Walch's attention was particularly excited by this peculiar *resinous* or *waxy gloss*, which he endeavoured to account for, by supposing that this petrified wood had been impregnated by a peculiar spathose matter; which had been deposited, whilst in a fluid state, and afterwards congealed. There appears, he says, commonly, in this wood, something which resembles amber, or rosin; and which has, by some, been actually supposed to be so, and to have assumed a stony hardness. This, he, however, concludes is not the case; but believes that this substance, as he had already asserted, must actually be a particular species of spar[*].

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[*] Traité de Mineralogie, tom. ii. p. 139.

Nothing certainly, as far as the evidence of the eye can be admitted, can more effectually favour the opinion, that the formation of this species of fossil wood has depended on a combination of siliceous and soft, or even fluid, bituminous matter, than the peculiar lustre which it possesses; which is precisely such as might be expected from the mixture of these two substances. Various specimens, indeed, seem to display the bituminous wood in all its several degrees of change; from its first assumption of a bituminous nature, to the acquiring of the state of pure translucid bitumen; and having obtained, in these several states, its present degree of hardness, from the introduction of the siliceous matter. In such varieties of this fossil wood, as manifest evident and strong traces of the original fibres, there seems to be reason for supposing, that the wood had not undergone the bituminizating operation, to such a degree as to have been thereby rendered a fluid bitumen. But that the wood, previous to its impregnation with siliceous matter, had been so far affected by its bituminization, as to have been rendered soft and yielding, is evident from the appearances which specimens of this kind of fossil wood generally yield. Their fibres will generally be seen disturbed, and thrown out of their natural direction; not as if broken, but as if displaced whilst in a yielding state, and thrown into gentle contortions, and undulations. An idea of what is here meant may be furnished by a view of Pl, II. Fig. 7.

[*] Recueil des Monumens des Catastrophes, &c. tom. iii. p. 32 and 39.

In Pl. I. Fig. 1. is represented a specimen of bituminous wood dug up at Blackwall; whilst digging for the purpose of forming the West-India docks. This specimen, as is often the case, displays no very decided traces of its original form: the fibres are irregularly grouped, and seemingly agglutinated together; leaving proportionate vacuities between them. Allowing imagination to fully imbue this mass, with siliceous matter, a substance resembling the common siliceous wood will be formed. The collected bundles of fibres will manifest its origin; and the siliceous matter, preserving its pellucidity in their intervals, will testify the nature of the impregnation, where the original arrangement of the fibres is almost lost. Thus may be illustrated the formation of such specimens as are represented at Pl. II. Fig. 8. and Pl. III. Fig. 9.

In many beautiful specimens of opaline fossil wood, the fibrous substance may be seen passing through various gradations of change. On the external surface, as at Pl. II. Fig. 9. and at Pl. III. Fig. 8. may frequently be seen the silicized fibre, nicely preserved, still retaining its natural colour, and not partaking at all of the resinous gloss, observable on the other parts of the same mass; whilst, as the same fibrous appearance enters into the substance of the mass, its lines are softened down, by its assuming this resinous-like appearance, and a much greater mellowness of colour; and is at last entirely lost by assuming the prevalent colour and appearance of the whole mass. Instances of this kind are frequently met with, and may be particularly noticed in the two specimens to which you have been last referred.

This appearance of the ligneous structure, on the external part of a specimen, and its gradual disappearance, on the internal part, is frequently to be perceived: sometimes also, whilst the external part thus preserves the appearance of wood, this appearance will almost suddenly be lost in the internal part, which has acquired a very high degree of transparency. This circumstance is particularly observable in Pl. III. Fig. 8. where the external surface is formed by a thin cortical coat, exactly resembling that of the inner cortical investment of recent wood. Another form, which, in these instances, the external surface sometimes bears, is that of apparently dried, and withered wood, as at Plate II. Fig. 9. Both in this, and in the other, the seeming cortical surfaces are pervaded by silex, but appear to be but little changed by bituminization; which may assist, in accounting for their not possessing the resinous lustre, which distinguishes the rest of the mass: numerous observations seeming to point out, that the bark, and dry withered wood, are not so susceptible of bituminous change, as those parts, in which the woody fibre is abundant, and unimpoverished.

Another circumstance, hitherto inexplicable, demands next to be noticed. In many specimens of siliceous fossil wood, are found disposed, in and about it, distinct masses of a substance, bearing so exactly the appearance of bitumen, as would leave no doubt of its being of that nature, were it not that examination discovers it to be a substance, containing a considerable proportion of silex. The explanation of the formation of this mysterious substance is, undoubtedly, accompanied with considerable difficulty. After having examined it in every point of view, I discover no mode of explaining its formation, but by supposing it to have been actually a fluid dark bitumen, which, by the medium of the water, we have already seen it contains, has become impregnated by siliceous earth.

The general appearance of this seeming bituminous substance appears strongly to point it out, as having existed in a soft state: some pieces of it appearing as if their eminences had been rounded off by slight friction. In the specimen figured at Plate II. Fig. 4. which has very much the appearance of a piece of fossil deal wood, this black bituminous-like matter almost covers one end, and penetrates into the substance of the wood, as may be seen by the section of the same specimen, at Fig. 5. of the same Plate: the wood having split at the end, as if from dryness; and the bitumen, in a fluid state, having apparently filled the rifts thus produced. This section, being polished, serves also to shew, that both of the substances, which enter into the composition of this specimen, are thoroughly penetrated by the silex: both having acquired the same brilliant polish, from the lapidary's wheel.

Another circumstance may be mentioned, in addition to those which have been already adduced, in confirmation of the opaline woods being formed, by the combination of bituminous wood and silex; which is, that they sometimes are marked by depressions, evidently from pressure against contiguous bodies; which depressions have every appearance of having been made, whilst the fossil wood was about the firmness of wax, or of tallow. In a specimen which I obtained, since the Plates intended for this Work were finished, a circumstance occurs, which seems to prove irrefragably the facility with which bitumen and silex may thus unite. One side of this specimen presents the ordinary appearance of bituminous wood, although the whole is well impregnated with silex. On the other side, part of the wood had began to suffer a change into jet, and is also covered, in detached spots, with a substance possessing that particular varnish-like lustre which has been so often mentioned, but is of a jet black. Many parts of the specimen are sprinkled with drusy crystals of quartz, which, in the neighbourhood of the jetty part of the wood, are also of a jet black, evidently from the intermixture of the fluid black bitumen with the silex, of which the crystals are chiefly composed. A difficulty may here present itself to you; and you may probably ask why, whilst this varnish-like substance is in all the other specimens variously coloured, it should in this be of a jet black? But I must call to your remembrance, that, whilst endeavouring to account for the blackness of jet, it was supposed that the black oxide of carbon (charcoal) was formed, by the carbon of the bitumen, attracting to itself the oxygen of some neighbouring substance; and, very probably, of the sulphuric acid: in agreement with this idea, there exist evident marks, in this specimen, of the wood having been exposed to the influence of sulphate of iron, previous to its impregnation by silex.

As siliceous, and even opaline wood, has been found in almost every part of the world, and as mention has already been made of many places where it is particularly abundant, all that seems necessary here, appears to be, to give a slight sketch of the differences which have been remarked, in the siliceous woods of various parts. Silicized wood has been discovered in various parts of England, but seldom any which displays any thing of the opaline lustre. A specimen, however, which I possess, from the neighbourhood of Wooburn, in Bedfordshire, has it in a considerable degree.

The petrified wood found in the neighbourhood of Lough-Neagh, which has been spoken of in a former part of this volume, is evidently wood, which, having suffered bituminization, has afterwards been impregnated with silex, partially or totally, and in various degrees; and has also, in some instances, become invested by the lapidified surrounding matrix. On examining a handsome specimen of the Lough-Neagh wood, in the British Museum, being of that kind which has been described as possessing the unchanged, continuous with the petrified wood, I was convinced of its being bituminized wood, in some parts involved in, and in others adherent to, a coarse, hard, argillaceous matrix. Mr. Barton himself says, "The smell (of the woody part of these stones) is not resinous, yet it is a strong smell, when it is burning in a large quantity; and a faint smell of the same kind, when only the stone is burning; perhaps, he says, this is the scent of bitumen*." The other kinds of Lough-Neagh wood are undoubtedly of the siliceous kind; he says of them, " They cleave like wood; they contain abundance of fire, as may be proved by using them as flints, and by rubbing them one upon the other, even when they are wet; and they bear the fire surprisingly; for although they are easily made red hot, yet they neither burn to lime, nor vitrify."

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* Lectures in Natural Philosophy, &c. by Richard Barton, B.D. Dublin, 1751, p. 89, &c.

In Switzerland, and particularly in the neighbourhood of Bayern, beautiful specimens of the silicized bituminous wood are found, bearing a very close resemblance to the recent wood in colour and figure. In Lithuania a rare kind is found, in which, though it manifests no disposition to the transparency, which the opaline wood in general shews, it possesses, in some parts, the opaline lustre, and has obviously, from the soft state in which it has existed, had its fibres so blended together, in a confused mass, that were it not for the knots, which are very evident, its ligneous origin would not be detected. Switzerland, various parts of Germany, Saxony, Hungary, and Bohemia, have indeed hitherto produced the most beautiful specimens. From the chain of mountains, formerly named Taurus, in Natolia, from the neighbourhood of Pergamo, and from some of the mountains of Italy, very interesting specimens are obtained. The fossil wood of Coburg, in the Circle of Franconia, is, in general, very beautiful; since it equals any in hardness, and is, consequently, susceptible of as fine a polish as any; and, at the same time, displays, very determinately, the ligneous texture. Bamberg also furnishes a fossil wood, very nigh approaching, in beauty, that of Coburg. The wood which is dug at Rockenhausen, and from the mountain at Kyfhausen, is eminently conspicuous for its beauty; its hardness almost equalling that of agate, and its intermixture with a white earth giving it also the character of jasper: an oxide of iron, frequently of a bright red, tints it very beautifully in various parts; whilst a few, but decided traces of wood, determine the wonderful change which it has sustained. The fossil wood of Chemnitz seldom displays very clearly the characteristic marks of the wood; it giving rather the idea of agate, or of jasper, which, in hardness, it fully equals.

That Saxony and Hungary, whence the noble opal is chiefly obtained, should abound in those siliceous woods which nearest resemble the opal in their lustre, is a circumstance which here demands our particular attention, since it will yield us some additional evidence, whilst determining on the question which will next require to be agitated.

LETTER XXXVII.

EVIDENT AFFINITY BETWEEN SILICIZED, BITUMINOUS, OR OPALINE WOOD AND PITCH-STONE....ANALYSIS OF OPALINE WOOD ....OF PITCH-STONE....SIMILARITY INFERRED.

As that particular character, a waxy, or resinous lustre, is evident in those substances which, though now chiefly formed of silex, display the most evident marks of their having been wood; and as nature does not multiply her agents unnecessarily; it does not appear to be unreasonable to suppose, that particular appearance has been derived, in every other stone which possesses it, from the same source, as that which has furnished it to the fossil wood. You will already have perceived, that I am leading you, with as little abruptness as I can, to the consideration of an opinion, which I suspect must demand some little management to secure it a favourable reception.——That the pitch stones, the semi-opals, and the noble opal itself, derive their peculiar characters from certain portions of the vegetable matter, which, having been buried at very considerable depths, at the time of the deluge, has undergone a particular change in the combination of its constituent principles; and, in that state, has been intimately united with silex. We will now proceed to examine, how far this position is supported, by the physical and chemical properties of these substances.

Among the most beautiful and frequent specimens of the opalized woods, are those which, from their near resemblance to pitch-stones, mineralogists have termed LIGNIFORM PITCH-STONES, the QUARTZ RESINITE XYLOIDE of Hauy. In these, the characters of wood are so distinctly marked, that no one can entertain the least doubt of their having originated from wood. The resinous, or waxy lustre, which they manifest has been already examined, as to the degree of evidence it affords of the wood having existed in a bituminous state. Their fracture, perhaps, serves also to further prove their ligneous origin; since, although this is in general conchoidal, it will frequently, when longitudinal, be splintery, and even fibrous, in the direction of the fibres of wood. Their colours vary very much, from milk white, through all the shades of brown and yellow, to green, red, and black: but their most frequent colours are those, which approach so near to that of the original wood, blended with that of common rosin, as to corroborate strongly the idea of the wood having been softened down, into a resiniform substance, previous to its impregnation with silex. Their transparency, which is sometimes such as to admit light through them freely, and even, when in thin slices, such as to allow objects to be seen through them, is a circumstance which it is impossible to account for in any other way so well as by supposing the wood to have been rendered a clear bitumen during its first change. A specimen of this kind of pitch-stone, or fossil wood, possessing in its internal part a considerable degree of transparency, whilst the external part bears the appearance of recent wood, is figured in Plate III. Fig. 8. These fossil woods are also characterized by a circumstance which has excited the admiration of mineralogists, and which at the same time seems to manifest the intermixture of some substance with the silex, which does not seem to exist in any other stone of the siliceous genus—although they appear, from their peculiar kind of lustre, to be little harder than rosin, and sometimes give fire with steel with difficulty, they yet are more difficult to be scratched than many that do.

The combination of bitumen and silex, in these specimens of pitch-stones, and fossil wood, is rendered still more probable, and even certain, by the chemical properties they exhibit when subjected to the action of fire, and of other appropriate re-agents. 120 grains of opaline wood, from the specimen at Pl. II. Fig. 4 and 5, were reduced to a coarse powder, and digested without heat, for two months, with 180 grains of pure pot-ash, and half an ounce in measure of water, when the whole of the siliceous matter became nearly dissolved, forming a thick *liquor silicum*; whilst the sediment which remained was considerably darkened, and became exceedingly light and flocculent; bearing the appearance of carbonaceous matter.

But to render the knowledge of the constitution of opaline wood quite perfect, I again had recourse to the abilities of Mr. Pepys; whose excellent report I here subjoin.

SPECIMEN OF OPALINE WOOD*.

Of a splintery fracture—gives fire with steel—takes a fine polish—of a brownish yellow colour.

For Carbonaceous or Resinous Matter.	A portion digested with alcohol, at ebullition, yielded no precipitate, nor cloudiness, on mixture with water. Pulverized, and digested, with concentrated sulphuric acid, nearly boiling, blackened the acid slightly. Projected, with nitre, into a red-hot silver crucible, produced no deflagration, nor appearance of carbonaceous matter.

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* Plate II. Fig. 4 and 5.

For its Solution.

Digested with the acids—sulphuric, nitric, and muriatic—it produced no change, except, as before noticed, with the concentrated sulphuric.

Heated with caustic pot-ash, in a silver crucible, it dissolved, and ran *per deliquium*, on exposure to the atmosphere.

THE ANALYSIS.

A

100 grains of the pulverized substance was heated with 200 grains of caustic pot-ash, in a silver crucible. The mass was then dissolved by 12 ounces of distilled water, and filtered.

B

To the solution A, nitric acid was added, as long as a precipitate formed. It was then farther diluted, boiled, and filtered. The precipitate obtained dried at 212°, weighed 126 grains: heated to redness, 110 grains.

C

As the precipitate B might contain a small portion of the pot-ash, it was boiled with 200 grains of marine acid, diluted, and filtered: when heated to redness, weighed 94 grains.

D

The filtre of the process A contained no extraneous matter. The solution of nitrate of pot-ash B, being completely neutralized, was crystallized; and from the mother liquor a precipitate of silex was obtained: weighed 1.5 grain.

E

The solution of muriatic acid C was neutralized by carbonate of pot-ash, and boiled; and proved free from precipitation.

100 parts of opal wood contain

			Grains.
Silex . . .	C	94	95.5
. . . . . .	D	1.5	
Loss			4.5
			100

Anxious to have the presence of carbon, in the opaline wood, still more plainly manifested, I again troubled Mr. Pepys; the result of whose obliging and ingenious labours I shall give you, in his own words; only omitting his well-adapted contrivance, for conducting his experiment with security and effect.

DEAR SIR,

CONCEIVING that a portion of the opaline wood being mixed with twice its weight of purified nitre, and exposed to heat, if carbon was present in the stone, it would unite with the oxygen of the nitre, and produce carbonic acid gas, I proceeded to the following experiment.

Into a coated glass retort, with a conducting tube entering a bottle of lime-water, 50 grains of fossil wood, and 100 of nitrat of pot-ash, were introduced; and it was then surrounded with heated charcoal. After the expansion of the atmospheric air, an absorption took place, from the fusion of the nitre; this was guarded against, by lifting the conducting tube from the water; as soon as gas was liberated, it was again immersed, and a copious precipitation, and cloudiness of the lime-water, ensued. This continued for some minutes; it was then succeeded by the liberation of oxygen gas, with nitrous gas, occasioning no precipitation in fresh lime-water. In 36 minutes the retort was perfectly white hot, and slight absorption began to take place: the retort was then removed, and when cool was broken: the mass was found strongly agglutinated, possessing a tinge of pink.

I am, with sincere respect, yours,
W. H. PEPYS, jun.

The presence of carbon having been thus proved, my next eager wish was to endeavour to discover the nature of this substance, which thus contained carbon as a principle; entertaining an expectation, that some evidence would appear, that it was vegetable matter, which had undergone the bituminizating process, or fermentation: I therefore requested Mr. Pepys, without mentioning my conjecture, to submit a portion of similar fossil wood, with that which had been employed in the foregoing experiments, to simple distillation, over a naked fire. This request was kindly complied with, and the result appears in the following letter.

SIR,

AGREEABLE to promise, I have made the experiment you requested. 250 grains of the opaline wood were pulverized, and placed in a coated glass retort; to which a tubulated receiver, with a conducting pipe, leading into a bottle of lime-water, was luted. Gradual heat being given, rarefied the atmospheric air in the vessels, which passed through the lime-water; in 15 minutes this ceased, and the retort being red hot, a small quantity of water dropped from the beak into the receiver; and, as it there collected, an *oily*, or sublimated film, appeared on its surface. The strongest heat of this furnace was continued about an hour; when evident absorption taking place, and the distillation ceasing, the operation was stopped. Upon opening the receiver, a *strong empyreumatic* smell was observed. The liquor obtained has a dull yellow colour, with small scales on its surface, and in quantity about 20 drops; the greatest part of the scaly substance adhered to the receiver on pouring out the fluid. The substance in the retort was still pulverulent, but much more white than when introduced. The liquid shews no acid properties, by the test of litmus paper, or violets.

I am, with much respect,

W. H. PEPYS, jun.

The *oily*, or sublimated film, and the *strong empyreumatic* smell, afford some reason for believing in the presence of bitumen in this opaline wood; but anxious, only for the discovery, and communication, of the truth, I wish you to suspend your opinion, until your judgment has been aided by other corresponding experiments, which I shall now adduce.

Common pitch-stone, that which displays no obvious trace of wood, *halbopal* of Emmerling, and, from its resinous or pitchy lustre, the *pierre de colophane* of De Lisle, and the *pierre de poix* of Daubenton, differs in no respect from the former kind, except in the absence of those marks which give to that a resemblance to wood. Believing this to depend merely on the bituminous wood, which enters into the composition of this latter substance, having become so fluid as to have had the remains of its fibrous structure quite melted down, whilst in the former some of the fibrous structure remains, I conceive it not entitled to be considered as of a different family from the former, as has been done by Mr. Kirwan, and other mineralogists. In proof of this opinion, we often see, in the same specimen, in one part, distinct fibrous appearances; in another part of the same substance, the fibrous appearance, we perceive, is quite lost; and, in the intervening part, the gradual departure from a striped, to quite a plain appearance, may be observed: whilst frequently the existence of the soft bituminous state will appear, from the wavy and contorted directions of fibrous stripes, which are indubitably of a ligneous origin. Nor does any difference of physical properties exist between this and the ligniform pitch-stone already described. With respect to their chemical properties, there exists a very close agreement, as will appear from the following experiments.

Mr. Pepys exposed 50 grains of pitch-stone, and 100 of pure nitrate of pot-ash, to the same treatment as he had subjected the same quantities of opaline fossil wood and nitrate of pot-ash, and reported that the phenomena which resulted were precisely the same.

At Menil le Montant, also at Saint Ouen, near Paris, and in several other parts of France, have been found a stone which is of a greyish colour, sometimes mottled with blue on its surface, opaque, generally of a tubercular form, and shewing at its fracture a slight lustre of the greasy kind. It was first described by Delabre and Quinquet, who very properly considered it as a new kind of pitch-stone; its hardness, specific gravity, and fracture, as well as its kind of lustre, warranting them in this opinion*. It was named, from the place where it was first found, Menilite, and was considered as a variety of the pitch-stone, being therefore termed, by some, blue pitch-stone: but it has been supposed by others to belong rather to the magnesian genus of stones, such as the pot-stone, steatites, and serpentine.

The experiments of the justly celebrated Klaproth, which induce him to consider this fossil, as a variety of the semi-opal, approaching to flint *(feuerstein)* serve strongly to corroborate the opinion I have offered, of substances possessing this peculiar lustre, deriving it from an impregnation with bitumen, and are in full accordance with the experiments of Mr. Pepys. Mr. Klaproth introduced 100 grains of this substance into a small glass retort, inserting its neck into a bottle containing lime-water. The retort was placed between the coals, or in open fire, and the heat gradually increased to the ignition of its contents. At the very beginning there passed over some drops of water, and soon after the lime-water in the receiver became turbid. In this last, when the receiver was removed, a *bituminous-empyreumatic* smell was perceived, which at first also seemed to be somewhat ammoniacal. The pieces of the stone, in the retort, were rendered black, and resplendent like jet; but by a still longer ignition, in an open crucible, they lost that black colour, and became at first bluish, then grey white, losing, at the same time, three grains more of their weight*.

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* Journal de Physique, Sept. 1787, p. 219.

The result of this operation, and particularly the *bituminous-empyreumatic* smell, afford pretty strong evidence in favour of the supposed nature and constitution of the substances of this genus.

Yours, &c.

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* Analytical Essays, by M. H. Klaproth, p. 452.

LETTER XXXVIII.

SEMI-OPAL....EXPERIMENT ON SEMI-OPAL OF TELKEBANYA.... OPAL....ITS WONDERFUL PROPERTIES....ANALYSIS BY KLAPROTH....HORN-STONE AND FLINT.

THE SEMI-OPAL is the next substance which, possessing this kind of lustre, demands our attention: but, previous to making any remarks on the nature of its constituent parts, it will be necessary to determine the propriety of placing it among those substances which possess the peculiar lustre, which I have supposed to belong to those substances, which are formed by an intermixture of bitumen with silex. The reason for instituting this inquiry is, that Mr. Kirwan describes the lustre of the semi-opal, and of the opal itself, as being of the glassy kind; which, being admitted, would prohibit both these substances from preserving the rank, which is here allotted them. This character, however, a glassy lustre, I believe, with the utmost deference to Mr. Kirwan, is not the legitimate lustre, at least, of the real external surface of the opal, or of the semi-opal. The lustre of its fragments, indeed, may be, and that which it receives from the polish of art generally is, of that description: but in an hydrophanous opal now before me, which, when dry, resembles a piece of white wax, and when in water is transparent, and resplendent with purple and a vivid green, the lustre, even of its polished surface, is decidedly resinous; and, most undoubtedly, the lustre of the actual external surface of the opal, that which was in contact with the matrix, is almost always of the waxy kind. The matrices, also, both of the opal, and of the semi-opal, present appearances, very strongly indicative of the presence of bitumen:

detached spots will be frequently seen on them, in the neighbourhood of the opal, presenting an appearance, very nearly resembling that which would be produced, by the spread of a fine resinous varnish. I should have been much more disposed to hesitate, in thus opposing Mr. Kirwan, on a mere object of sense, if I had not been supported by one of the latest authorities, on such a point, the Abbé Hauy, who places the opal, the semi-opal, and the hydrophanous opal, among those substances which, from their lustre resembling that of newly-broken resin, he distinguishes by the generic term of *quartz-resinite.*

The analysis of Mr. Klaproth having been made, chiefly, with a view to the ascertaining the nature, and proportion of the earths, contained in the substances he examined, the first part of his operation was, generally, ignition, in an open crucible; by which the water, and other volatile matters, must have been indiscriminately dissipated. Such was the mode in which he made an examination of the brown-red semi-opal of Telkebanya; and even thus a circumstance occurred, which did not escape his nice observation, and which tends strongly to evince the probability of this semi-opal containing a portion of that matter, on which I presume the peculiar lustre of substances of this class depends. Mr. Klaproth was surprised to find, on igniting this substance in the clay-crucible, that its whole surface was covered with a fine scaly ferruginous crust, of a metallic lustre, and attractible by the load-stone. This, Mr. Klaproth says, is, indeed, an unexpected phenomenon; and hence the more remarkable, that iron, so strongly oxided, as it is when contained in this fossil, was, in this instance, reduced to the reguline state, so as to obey the magnet; and this, without any admixture of charcoal, or any other substance of a nearer affinity with oxygen*. If I were constrained to rest the support of the opinion I have formed on any single experiment, I hardly know any which I should prefer to this of Mr. Klaproth's. According to the opinion offered, this substance does contain bitumen, into the composition of which carbon enters, in an abundant proportion—and, by the experiment, an effect is produced which excites the astonishment of this excellent chemist; because it is that effect, which he would have expected from the presence of charcoal; which he had no conception entered into the composition of the substance, which was the subject of his experiment. Having obtained this satisfactory evidence, from the analysis of the semi-opal; the task remains to ascertain, whether any traces of this substance are to be discovered, in the opal itself.

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* Analytical Essays, p. 440.

The OPAL, *opal edler, gelber opal,* Werner, the noble opal of some, and the oriental opal of the jewellers, in addition to the general characters which distinguish this class of fossils, possesses the astonishing property of displaying, in a strong light, the most vivid and beautiful colours, which continually play on the eye, with varying splendour, on the least change of position. From that spot which, the instant before, shewed a beautifully bright green, or purple, a rose-coloured flame suddenly darts forth, forming what the amateurs of this stone term, *the fire of the opal.* But description can furnish only a very imperfect idea of the brilliant display of colours, yielded by this admirable, and inestimable jewel. Our admired poet Thomson appears to have succeeded, as far as the powers of language could enable him. It is in his address to the Sun, where he thus speaks of the wonderful properties of this highly elaborated work of nature.

> The unfruitful rock itself, impregn'd by thee,
> In dark retirement forms the lucid stone:.
> The lively *Diamond* drinks thy purest rays,
> Collected light, compact, that polish'd bright,
> And all its native lustre let abroad,
> Dares, as it sparkles on the fair one's breast,

With vain ambition emulate her eyes.
At thee the *Ruby* lights its deepening glow,
And with a waving radiance inward flames.
From thee the *Sapphire*, solid ether, takes
Its hues cærulean; and, of ev'ning tinct,
The purple streaming *Amethyst* is thine.
With thy own smile the yellow *Topaz* burns:
Nor deeper verdure dyes the robe of Spring,
When first she gives it to the southern gale,
Than the green *Emerald* shows: but *ALL COMBIN'D*,
Thick through the whitening OPAL play thy beams,
Or, flying several from its surface, form
A trembling variance of revolving hues,
As the site varies in the gazer's hand.

SEASONS, Summer, l. 140.

Mr. Klaproth, having subjected the noble opal, both in its ordinary, and in its hydrophanous state, to the test of his accurate examinations, is induced to conclude, that the difference between it, common flint, and rock crystal, is only that which depends, on a difference in the state of aggregation*. From this same examination, I am led to make a widely different inference; and to conclude, that the same bituminous matter, which has been assumed to be present in the other stones of a waxy lustre, is also present in the opal; and that it is by its admixture with the simple, pure, siliceous earth, that the opal is produced. In two of Mr. Klaproth's experiments, which, being made merely to ascertain the nature of the earth existing in this stone, prove the quantity only of its volatile parts, the real constituent parts of the opal are shewn to be,

	Gr.
Silex	90
Water, and other volatile matters	10
	100

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* Analytical Essays, p. 440.

Another experiment was made on one of those varieties of the opal which are known by the names *hydrophanes*, *changeable opal*, and *oculus mundi*, which, besides possessing the remarkable property of becoming transparent in water, and other fluids, are eminently distinguished by manifesting, in that situation, the beautiful play, or change of colours, peculiar to the opal. This analysis was made, under those circumstances, which were calculated to yield some knowledge of the nature of those constituent parts, which had been dissipated, without examination, in the two experiments just mentioned; and therefore is the experiment, on which might, almost, be allowed to depend the decision of the question—whether any thing of a *bituminous* nature enters into the composition of the opal. The result of this experiment is strongly affirmative of this fact; and, indeed, seems to confirm the opinion I have ventured to advance, in a most striking manner. You must have perceived that I have been regularly led on to the supposition of the presence of bitumen in opal, by first noticing the impregnation of bituminous wood with silex, by which was formed silicized bituminous wood; then tracing this into the opalized wood and the pitch-stone; thence to the semi-opal, and at the last to the opal itself: you will therefore readily conceive the satisfaction yielded by the analysis made by Mr. Klaproth, which afforded a result at once so unexpected, and decisive; and so precisely accordant with the experiments of Mr. Pepys, on opaline wood.

One hundred grains of the hydrophanous opal of Saxony were coarsely divided, or bruised, and ignited upon red-hot coals, in a small glass retort. At the end of this process there appeared, in the receiver, an *empyreumatic water*, covered with a thin *greasy pellicle*. The loss of weight arising from this was 5¼ grains. Pursuing the analysis, Mr. Klaproth was enabled to ascertain that 100 parts of the hydrophanous opal, from Saxony, contain,

	Gr.
Silex	93.125
Alumine	1.625
Volatile *inflammable* parts, and water	5.250
	100*

The opinion which I have ventured to offer, respecting the transition, if I may be thus allowed to employ the term, of bitumen, into the noble opal, appears to be corroborated, and the fact to be illustrated, by another modification of bitumen and silex, in which the union of these two substances appears to be incontestable. In the specimens in which this combination occurs, and which evidently are of vegetable origin, the external surface presents evident marks of wood, which appears to have undergone but a slight degree of bituminization. This ligneous coat is, in some parts, not more than a sixteenth of an inch in thickness, and in some parts is so thin, as merely to give the appearance of a film; adhering to a flinty matter, of which the substance is formed. This substance differs in no respect, in its appearance, from COMMON FLINT (gun-flint, *feuerstein)*, except in being more dull and opaque; as if it contained a portion of dark-coloured bitumen, or petroleum: this appearance being rather more conspicuous, towards the external surface; it gradually assuming the appearance of common flint; and, acquiring a greater degree of pellucidity and transparency, as it reaches the interior surface: and, in one specimen, it there assumes the form and appearance of a calcedonic stalactite.

The film, or coat, bearing indisputable marks of ligneous origin, whilst the rest of the mass appears to be formed by the blending of bitumen and silex, offers an appearance, not to be explained, without some difficulty. An analogous circumstance is frequently observable in pieces of asphaltum and jet; the bituminous change being entirely completed, except at the surface, where the texture, and sometimes the colour, with the other characters of the wood, will be manifest. This ligneous appearance, as in the case above mentioned, is generally merely superficial; although sometimes, indeed, the fibrous appearance will extend for a quarter of an inch, or more, into the mass of bitumen. The explanation which will be satisfactory in the one instance, will also suffice for the other. We are, in the first place, necessarily led to the conclusion, that, by the influence of some adequate cause, the surface of the wood had been rendered less susceptible of the bituminous fermentation, than the other part of the wood, and has therefore remained unaltered, whilst the other part has completely undergone the bituminous change. The causes to which this may be attributed, are either, first, a natural disposition in the exterior surface of wood, and particularly in the bark of trees, to resist the influence of the bituminous fermentation: secondly, the previous impregnation of the external surface, with some earthy, or metallic saline substance, which might render it incapable of undergoing the bituminous change, so deep as that impregnation might extend itself. This opinion is strengthened by the specimen, Plate III. Fig. 8. in which the internal part is opalized, and rendered nearly transparent, whilst the external part has the appearance of wood itself, and is marked externally, in several parts, of a blue colour, as though it were impregnated with carbonate of copper.

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* Analytical Essays, p. 444.

In the specimens above mentioned, in which the combination of *dark-coloured* bitumen and silex is apparent, analysis appeared to be unnecessary to prove the presence of the bitumen, it was therefore omitted, especially as it could not have been accomplished without injuring two valuable specimens.

The examination of specimens of this kind, and of their transitions, in such a manner as to ascertain what volatile matters enter into their composition, would, perhaps, shew the unexpected presence of bitumen both in horn-stone and flint. When it is considered how numerous the substances are, into which the transition of fossil wood may be traced, a wide field opens for similar inquiry. Indeed, whilst contemplating a siliceous mass, which accompanied, and was even blended with silicized bituminous wood, and which emulated the emerald in its lustre, and beautiful green colour, I have been prompted to suspect that some of the coloured stones might, perhaps, be indebted to vegetable decomposition, for the charming hues which they display. I feel so much assured, that, from the application of the powers now possessed by chemistry, in the examination of mineralized wood and its transitions, a rich harvest would be yielded; that it is with regret I reflect on my own want of opportunity for so interesting a research. From such inquiries we should learn the real nature of the various colouring matters, with which these substances are so pleasingly tinted; and be enabled to determine whether they depend at all on modification of bitumen, or are derived from metallic substances alone. The fossil woods would themselves thus furnish ample matter for investigation; since they are frequently variegated with the most pleasing colours; amongst which may be particularized, besides the brown, so obviously derived from bitumen, and which is often enlivened by a rich and bright yellow;—green, from the darkest olive to the faint sea-green;—and red, from the faintest pink, almost to crimson.

It is true that, on examining a very curious specimen—a large nodule of flint, containing a piece of silicized wood in its centre, little or no increase in the darkness of its colour is observable in the flint which immediately surrounds the wood. But this perhaps may be accounted for, by the wood having been of that light, white, and shivery kind, which, as has been already observed, is not liable to undergo much change from bituminization. Its colour is now of a very light grey; and therefore, as it has been most probably penetrated by the dark siliceous fluid of which the flint was formed, its original colour may be reasonably supposed to have been very nearly approaching to white.

Yours, &c.

LETTER XXXIX.

CALCAREOUS WOOD....LIME FREQUENTLY HELD IN SOLUTION, IN WATER....VARIOUS FORMS OF DEPOSITION....*CONFETTO DI TIVOLI*....QUARRIES OF TUFACEOUS STONE....STALACTITIC CAVERNS.

THE mineralized wood, of which we shall treat in this Letter, is of such a nature as will not oppress us with such difficulties, whilst endeavouring to ascertain its mode of formation, or the nature of its constituent parts, as were opposed to our inquiries, respecting the same subjects, whilst examining siliceous wood; since the nature of the mineralizing matter is such as to allow its removal by such agents, as will not act so destructively on the vegetable matter, which forms the *substratum* of the fossil.

CALCAREOUS WOOD, wood impregnated with lime, is neither so hard nor so heavy, as siliceous wood; it may be scratched by a knife, even in its hardest parts; and in some parts will allow of being cut, almost like recent wood: its hardness, and its gravity, depending on the degree of its impregnation with earthy particles, are of course variable and indeterminate. If exposed to the action of the mineral acids, its stony parts are dissolved with effervescence; and the vegetable parts are left: by the action of fire the stony parts are reduced to pure lime, whilst the vegetable matter is consumed.

As in the siliceous, so in this species of fossil wood, it is evident, that the lapidifying matter has been deposited from a fluid holding it in a state of solution. Pursuing, therefore, the same course as was chosen, whilst endeavouring to determine the mode in which siliceous wood had been formed, we will endeavour to discover the source of this impregnating matter. But little difficulty, however, presents itself here, since in almost every part of the world, springs and rivers exist which contain a considerable proportion of calcareous earth, which is deposited in the form of that species of carbonate of lime, which is termed *tufa*, on the sides of the channels through which these waters flow; and, indeed, on every substance they meet with in their current.

In England the waters of this kind are very numerous, particularly in the counties of Derbyshire, Yorkshire, and Somersetshire; but indeed their occurrence is much too frequent to allow of being particularized; a few only of the most remarkable circumstances respecting them can be noticed.

Dr. Plott relates* that, in Oxfordshire, there are incrusting waters at Somerton; at North-Ashton, in a field north-west of the church; in the parish of St. Clement, in the suburbs of Oxford; about a quarter of a mile distant, on the right hand of the first way that turns eastward, out of Marston-lane. But much better for this purpose, he observes, is the water of a pump at the Cross Inn, near Carfax, in the city itself.

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* The Natural History of Oxfordshire, p. 34.

The Doctor also mentions several springs of this kind in Staffordshire, and remarks that lapidescent springs deposit thin earthy matter on some plants, and not on others, though growing together in the same group. Mr. Wallis* also speaks of a brook at Simonbourn, where, he observes, the mosses and liverworts become stony; whilst the primroses and geraniums hold up their heads, and retain their native hue.

Dr. Plot also relates†, "that at Daulton, on the south side of Mendip, the workmen saw out of great blocks of stone, of four or five ton weight, which have been dug from the quarries there, large pieces of fair cleft oak included in the midst of them." Speaking of the growth of stone, the Doctor proceeds to say, "This is as indisputable a proof as any I have met with, except one at Newcastle-under-Line, in this county; where, at a place called the Gallows-tree (the ancient place for the execution of the malefactors of that town), there was found, within memory, in a firm block of stone, dug out of the quarry there, an entire skull of a man, with the teeth in it, &c. whereof Mr. Weever, an alderman of that town, told me he had one, long in his possession: which place, when used for executions, 'tis like might be nothing else but sandy land, wherein they used to bury the executed bodies, which in process of time has thus turned into stone." The deposit of lapideous matter from the waters in the neighbourhood of Mendip has been lately instanced, according to a very interesting paper on the subject, in the Philosophical Transactions, by its having thus partly filled up a cavern, and having incrusted, in a very curious manner, human bones, which had been there deposited.

Near the western bank of the Derwent, at Matlock, is a spring, well known by the name of the petrifying spring, and by the various substances, which accident and contrivance has occasioned to be invested with the calcareous matter which it deposits, such are twigs of wood, moss, birds-nests, &c. Even old wigs and hair-brooms are subjected to the power of these waters, to furnish subjects of amusement to the visitors at this place.

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* The Natural History of Northumberland, p. 24.

† The Natural History of Staffordshire, p. 171.

The waterfalls of Italy used also to supply the light-hearted with amusement; small white oblong, or round concretions, being formed by them, which have much the appearance of sugar-plums. These are put up in boxes, which are ornamented in the mode usually employed for boxes of sweet-meats, and thus offered to strangers, who, being frequently thus deceived, become the subjects of a harmless laugh. Those concretions, which are thus employed at Rome, are known by the name of *Confetto di Tivoli*, from their being chiefly obtained from the river Tiverone, the *Anio*, *Anien*, and *Anienus*, of the ancients, which waters the charming town of *Tivoli*, the favourite *Tibur* of Horace. The same name is, however, generally used for such as are obtained from the other rivers.

A much more rational and pleasing application of this natural process is made at the baths of St. Philip, in Tuscany. Dr. Leonard Vegni has established there a manufactory, to precipitate this fine *tufa* on medals and bas reliefs, and to get by that means the finest impressions. He causes this hot incrustating water to fall, from on high, into a large vessel, and to break upon a wooden cross; whereby it is separated into a fine spray, and directed against the sides of the vessel, on which, all around, the medals or bas reliefs, or their mouldings or forms, are hanging. The falling or breaking of the water imparts a greater impulsion to its drops, and to its *turfo* or *tartaro;* which, without this manipulation, would be but farinaceous, friable, and spongy. Mr. Ferber, from whose work the above account of this process is extracted, says, that Dr. Vegni has succeeded already in casting busts of this *tufo*, and he soon hopes to cast statues of natural size*. Since the publication of the above account, I learn that Dr. Vegni has applied the waters at Tivoli to the same ingenious purposes.

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* Travels through Italy, p. 245.

Pere Feuillée relates, that the petrifying waters near Guankabalika are applied to similar purposes; he having seen many very fine statues and vases in the churches at Lima, which had been thus formed in moulds, by earthy depositions.

Some waters are so replete with earthy particles, as soon to clog up the channels through which they are conveyed. A remarkable instance of this kind occurred at High Littleton, in the county of Somerset, about midway between Bristol and Wells. A pipe had been erected to convey away the waters, which had incommoded the workmen in a coal-pit: it was formed of elm, in shape nearly a long square, being about seven inches and a half one way, and four inches and a half the other. Through this, placed perpendicularly, the water was conveyed down to the level, or passage out, the trunk being about fourteen yards in length.

This trunk, having thus been fixed up in the latter end of the year 1766, was in about three years time, or rather less, found to be much obstructed, and stopped up, so that, in August 1769, the miners were obliged to take it up: and then, on examining it, and taking it to pieces, they found the whole cavity, from one end to the other, nearly filled with a sparry incrustation, somewhat softer than marble, but harder than alabaster*.

Strabo relates that the waters of Hierapolis, a city of Phrygia, were possessed of this property†. Pliny also notices similar waters‡. About fifteen miles from the city of Lucca, in Tuscany, is a spring, which arises from a mountain named Corsena; the waters of which, being made to pass through pipes, soon clog them by an accretion of stony matter.

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* Philosophical Transactions, vol. lxviii. p. 241.

† Strabonis de Situ Orbis, lib. xiii. p. 600. Basilæ, 1549.

‡ Lib. ii. cap. 103. Lib. xxxi. cap. i.

had the stony matter filled up this cataract, as to shut up the waters, though accumulated to a great depth, in the marshes of Reate: threatening to swallow up the delightful fields of the Reatines, in a permanent lake. To prevent this mischief, the Roman Senate sent M. Curius, who drew off the river from the lake, and led it into the Nera, through a new channel, cut between the mountains. The nature of the waters, however, occasioned the advantages derived from this expedient, to be but of short duration: for the accumulating stone had began to narrow the channel so much, that the inhabitants of Terni *(Interamnates)* foresaw danger to themselves; they therefore complained against the Reatines, whose cause was defended by Cicero. After this, during the reign of Tiberius, when the danger became more evident, and the *Interamnates* had reason to complain, that all their possessions might be taken from them by a single flood, they petitioned, that access might be given from the river to the lake, by a channel, leading back from the side of the aqueduct, formed by Curius. This was ordered by Tiberius to be performed; but the peculiar property of the water resisted the endeavours of Tiberius, as well as those of Curius. The straight, as well as the reverted channel, became filled with stone; and the river, possessing itself of the course, which it had at first, emptied itself into the lake, which, not being able to retain it, there being now no opening, it again overflowed the Reatine marshes. The Reatines were therefore anxious to open the cataract which had first of all been closed up by the stone; but this alarming the *Interamni*, great disputes arose, which would have terminated in a war between these people, if the Pope, Paul III. had not interfered. He directed the old cataract to be opened; and, lest its immense force should terrify the *Interamnates*, he moderated its violence by making three additional openings, thus carrying off the waters by four outlets. All these

Count Stolberg informs us*, that immediately beneath the ancient city wall of Posidonia, Pœstum, or Pesto, a rivulet runs, which has a petrifying quality, that was remarked as early as Strabo. Its banks are reedy, and some little hollow pillars bear evident marks of being themselves petrified reeds.

The waters of the *Solfatara*, or *Lago di Bagni*, abound with calcareous earth in solution. Cardinal D'Este had a canal dug, by which the waters of this lake should be carried into the Anio, to prevent their overflowing: but it is remarked by Breislak†, that the calcareous deposition is so abundant, that if they did not clean it every three years, it would be closed up, notwithstanding its width and depth. Its waters, like those already mentioned, cover with a calcareous crust the rushes, and other bodies it finds in its course. When the calcareous crust, thus formed, is only a congeries of *fistulæ*, or pipes, possessing but little substance, the name of *syringites* has therefore been applied to them; but when they are of a thicker substance, and have their openings almost closed, they are sometimes named *osteocollæ*.

It appears to have been by the formation of a curious species of incrustation, in this manner, that nature pointed out to art the application of this property of these waters. This species of incrustation, represented Plate III. Fig. 2. is termed *Lapis Sarnius;* it is formed of a tufaceous incrustation of very small twigs, leaves, &c. but bearing on its surface most correct impressions of the leaves on which it had been formed. These stones have been termed Sarnian, from a river in Campania (Terra di Lavoro) of which the poet thus speaks:

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* Travels through Germany, Switzerland, Italy, and Sicily, by Frederic Leopold Count Stolberg, vol. ii. p. 112.

† Voyages Physiques & Lythologiques dans la Campanie, par Scipion Breislak, t. ii. p. 262.

wooden hovel, for a more durable and pleasant mansion. Thus, we see, man is driven by a predestined, and apparently cruel, necessity, to the exercise of those powers, and the invention of those arts, by which his happiness and welfare is promoted; and is forced, by a most salutary, but mysterious, influence, to make his destined advances, in the progress of civilization.

Thus we find that almost all the houses in the neighbourhood of Matlock, and in some other parts of England, are built of this kind of stone, which is found exceedingly durable. The mountain of Tivoli, formed by this species of calcareous deposition, has furnished, time out of mind, the greatest part of the stones which have been used at Rome. This stone is usually called *Travertin*, a corruption of the word *Tibertin*. The front of St. Peter's Church is built with it; and the Colosseum, according to Misson*, is covered all over with it. Count Stolberg also observes, that its upper part is formed of a light porous stone. Breislak says†, at the foot of the mountain of Tivoli, where the Anio enters the plain, which reaches to Rome, are the quarries of Travertin. Independently, he says, of the immense quarries, dug by the ancients, there are others of such a vast extent, as will be sufficient to supply the demand of a great number of ages.

Nor is this deposition of stony matter confined to the surface, since this petrifying process is likewise carried on, in immense caverns, at some depth in the earth; where immense quarries of stone are thus formed, and laid up in store for man's future use. Through the roofs of these caverns, the pellucid solution of carbonate of lime filtrates, and deposits, from the moisture left of every falling drop, the spar it contains: forming, by the growth of ages, innumerable stalactites, which depend, like icicles, from different parts of the ceiling, in various sizes and forms. On the floors of these caverns, also, the repeated drops, as they fall, deposit their solid matter in stalagmitic heaps; which rising by the gradual, but constant accretion of fresh matter, acquire frequently a considerable degree of magnitude, and assume various fantastic forms. On every part of the sides, also, the trickling drops deposit innumerable minute crystals; and here also, from the same source, numerous stalactites become disposed in an arrangement, more approaching to regularity.

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* Misson's Travels, vol. ii. p. 66.

† Voyages Physiques & Lythologiques dans la Campanie, par Scipion Breislak, tom. ii. p. 262

The entrance to a cavern of this kind, is, in general, by a narrow opening, beset on every side by *striæ*, formed by the exuding spathose matter; and which, if not interrupted in its accumulation, would entirely close the opening. On passing this, and arriving at the cave itself, the mind is almost overpowered by astonishment, at the novel scene. The ceiling appears to be supported by columns of the most pleasing colour and elegant shapes, formed by the union of opposite stalactites and stalagmites: whilst others are seen in various degrees of approximation to each other, and assuming the most strange and uncouth shapes. Some hang from the roof, in the form of an inverted cone; some spread out in branches, not much unlike those of a chandelier; whilst others form in slender and almost transparent tubes, reaching nearly to the bottom. From the floor numerous rugged pyramids arise, intermingled with various figures, to which fancy attributes some strange and unexpected resemblance, such as to altars, animals, trunks of trees, &c. The ornaments on the sides render the effect on the mind, of this seeming magic scenery, complete. The light of the torches employed in these subterranean explorements is reflected in myriads of brilliant sparks, from the crystalline surface with which the walls are covered; whilst globular excrescences of yellow spar give the appearance of balls of gold, projecting from a white, and sparkling ground of diamonds. Frequently the slender stalactites, mentioned as adhering to the walls, will be so arranged, as to resemble the pipes of an organ; and, on being struck by any hard substance, will contribute to the delusion by sending forth a dull, but ringing, musical sound. The grotto of Antiparos; the Baumannian cave in the neighbourhood of Blankenberg; the caves in the Hercynian forest; the grottoes of Arcy, in France; of Chaumont, in Normandy; those astonishing natural excavations in Derbyshire, and various others, may be considered as so many laboratories in which nature is discovered, in her deep and secret recesses, unintermittingly employed, separating, from the rude materials, the finer species of stone, and amassing it in vast and inexhaustible stores.

To ascertain the circumstances, on which the deposition of the calcareous earth from different waters, immediately depends, would require a careful analysis of the separated matter, of the waters, from which the deposit is directly made, and of the different tributary streams; as well as an examination of the strata, through which they pass, and the various circumstances, under which they flow. But, in this place, it will be sufficient to point out to your notice, those properties of this earth, by which its solubility in water, and, consequently, its precipitation, will be chiefly affected.

Lime, in its pure state, is soluble in about 700 times its weight of water, at the temperature of 60°, and thus forms common lime-water; but if to this a small portion of carbonic acid be added, it unites with the lime, forms a carbonate of lime, and precipitates in an insoluble state. If, on the contrary, such a quantity of carbonic acid be added as will completely saturate the lime, it is again rendered soluble in water: and it is thus that carbonate of lime, held in solution, by an excess of fixed air, not in actual combination with the lime, but contained in the water, and acting as a menstruum, is commonly found in all waters*. A separation of carbonate of lime from waters holding it in solution may therefore result from two opposite causes; an absorption of carbonic acid, from the atmosphere, or from some subterranean source; and the loss of that part of it, which exists in excess, and which may be driven off by heat, or forced into other combinations, by the combined agency of different affinities. A farther investigation of the circumstances on which these depositions depend, does not appear to be necssary, it seeming to be sufficient to have ascertained that water, saturated with carbonate of lime, is not only flowing over various parts of the earth's surface, but is also transuding its substance, in almost every direction. That it should therefore impregnate, with its earthy particles, any substance, which, like bituminized wood, or any decaying organic substance, might be fitted to receive it, appears to be highly probable: and that calcareous fossil wood may have been formed by such an impregnation, and under such circumstances, every character which it possesses, both physical and chemical, serves to demonstrate.

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* Analysis of Mineral Waters, p. 15.

Yours, &c.

LETTER XL.

CALCAREOUS FOSSIL WOOD....WHERE FOUND....CALCAREOUS WOOD OF OXFORDSHIRE....DORSETSHIRE....SOMERSETSHIRE....ANALYSIS....MIXTURE OF SPAR AND BITUMEN....CALCAREOUS WOOD OF NEW SOUTH WALES....ALUMINOUS WOOD, &C.

It has been said, that calcareous wood is found, in various parts of the continent, and particularly in the neighbourhood of Arundsee, in Brandenberg; near Joachimsthal, in Bohemia; at Schemnitz, in Hungary; and in several parts of Wirtemberg, Franconia, Lower Saxony, &c. But from the very few specimens of this kind of wood, which we obtain from the continent, and, indeed, from their being so little dwelt on, by the French and German writers on fossils, it seems that they exist more plentifully in this island, than elsewhere. The specimens which are in most repute, for their beauty and preservation, are those which are found in Dorsetshire, in the neighbourhood of Charmouth; in Somersetshire, particularly in the neighbourhood of Bath: handsome specimens have also been found in Derbyshire, Devonshire, Oxfordshire, and in many other counties of England.

The appearance of the wood, in this species of fossil wood, as well as in the siliceous, shews that the wood, which has been thus petrified, existed, previously, either in a dry and shivered, or in a bituminous state. A specimen, from Oxfordshire, is described in Plate VI. Fig. 16. It is of a pale ash colour; and the light and fragile woody fibres may yet be seen very plainly, although much broken, intersected, and separated by the crystallizations of the calcareous spar, which has pervaded every part. The substance of this fossil is rather tender; yielding, sometimes, even to the force of the fingers. Its gravity is of course considerably less than that of siliceous wood. Although the greater part, by far, of its bulk is formed by the spathose matter, yet the form of the wood is tolerably well preserved: the natural direction of the fibres of the wood seeming to have directed, for the most part, the crystallizations into striæ, converging towards the centre of the wood, as may be observed in its section, shewn at Fig. 2. of the same Plate. Distinct masses of crystallizations and veins of spar may frequently be observed to penetrate its substance in various parts.

A specimen of the Charmouth fossil wood is represented in Pl. III. Fig. 9. The colour of this kind of fossil wood is darker than the former, it being of a deep brown colour. It is harder than that which has been just described, and heavier, inasmuch as it possesses hardly any vacuities. The texture of the wood is very evident, and even the knots of the wood are frequently perceptible: but, as in the Bovey-coal, so in this fossil, the woody fibres are distorted in various directions, in such a manner as could not have taken place, if they had not been in some degree softened. The calcareous spar, which permeates the wood through every part, marks it in many places with streaks of a beautiful pearly white, formed by the deposition of the spar from its infiltrated solution; and when this happens to have been the case in a cavity rather larger than the others, such an arrangement of the particles of the carbonate of lime will sometimes take place, as is observed in cavities large enough to allow of the formation of stalactites, and the cavity will be found to be filled with striated or fibrous carbonates, or alabaster. Thus, under one or the other of these forms, will the carbonate of lime be found to fill every cavity and rift in the wood, which had been produced by the mechanical action of the water in which it had lain, or by subsequent shrinking of the wood.

The calcareous fossil wood which is found in the neighbourhood of Bath, and of which a specimen is depicted in Pl. VIII. Fig. 4. resembles very much in colour that of Charmouth; but is harder, and retains, still more perfectly, the form of the wood. In the particular specimen, described in the Plate, although the spar so penetrates the mass, as to accompany the fibres, in all their directions, in threads, so minute as to be discovered, in many parts, only by the aid of a lens, of no small power; besides being pervaded through its whole substance by a mass of spathose matter, about half an inch in width; still the fibres of the wood are nearly as evident, on the polished surface, as if they had undergone no change.

Whilst inquiring into the nature and origin of siliceous fossil wood, I ventured to attribute ts formation, to the impregnation of wood, chiefly, in different stages of bituminization, with siliceous earth; but was unable to adduce any direct, and positive, evidence, in favour of this opinion, owing to the refractory nature of the silex, which demanded such agents to effect its separation, as would not fail to occasion a decomposition of the vegetable, or bituminous matter, with which it was combined. In calcareous fossil wood, which I suppose to differ from the former, merely, in the nature of the earth thus introduced, the same difficulty does not exist; since it will yield to the action of less destructive agents, and will allow of the complete separation of the superadded, from the original matter. Thus, by the addition of any of the mineral acids in a state of dilution, it might be expected that the carbonate of lime would be decomposed, and that the interposed particles of earth might in this manner be removed, leaving the vegetable or bituminous matter, in that state, in which it existed, when its particles were first, perhaps some thousands of years since, involved in this stony mass. The result of such an experiment must also afford some elucidation of the question, respecting the formation of siliceous wood; since if the original matter could be plainly made out, in the case of calcareous fossil wood, the inference would undoubtedly be admitted, that it was the same in the siliceous fossil wood.

A piece of the light-coloured fossil wood of Oxfordshire, already described, was immerged in nitric acid, diluted with about four times its bulk of water; a considerable degree of effervescence ensued, which lasted several hours; at the end of which time, the carbonate of lime being completely decomposed, the original matter of the wood had fallen to the bottom, in the form of a dark, fine, umber-coloured, flocculent sediment; the carbonate of lime having been so thoroughly diffused between these light particles, as to have been their only bond of connection. A portion of this sediment, after having been washed and dried, was placed on a red-hot iron, when it directly inflamed, and was quickly consumed, diffusing a strong bituminous odour.

A piece of the Charmouth fossil wood being immerged, in similar diluted nitric acid, a violent effervescence took place, during which some light particles were detached; but at the end of twelve hours, the effervescence having ceased, the fluid was poured off, when a dark brown, friable, but coherent mass, bearing every appearance of bituminous wood, was found. This being repeatedly washed, and afterwards dried, was exceedingly light and brittle, but still retained the form and colour of bituminized wood. On being applied within an eighth of an inch of the flame of a candle, or of any substance heated red hot, it caught fire, and burnt like touchwood, without inflaming; but, if brought into contact with the flame, it yielded a white flame. The appearance it made, whilst burning, from the spread of the fire through its substance, from its phosphoric glow, and from its brilliant white lambent flame, resembled very much that which is yielded by the burning of *pyrophori.* In whichever way the combustion was directed, a strong bituminous odour was experienced. A piece of the Bath fossil wood being exposed to the same trials, furnished exactly the same results.

The residuum thus obtained from calcareous fossil wood, furnishes us with considerable information, not only respecting the state in which it existed, previous to its petrifaction, but also in regard to the mode in which this process has been accomplished. After considering its properties, we must surely conclude, not that —*the more fixed, earthy parts, deprived of their oily, and volatile matters, had been combined with the lapidific matter*; nor that—*a* SUBSTITUTION of stony, *in the place of organized matter, had taken place;* nor that—*the lapidifying matter had been injected, whilst melted by heat, into the interstices of the combustible substance:* but, we should rather infer, from the high degree of combustibility, and even of inflammability, possessed by this residuum; and by the form it retains, that the original woody substance, either previous to, or during, the early periods of its envelopement with stony matter, underwent a change by which it became much more susceptible of the action of fire; or, in a word, acquired a bituminous nature: in which state it now presents itself on being freed from its stony impregnation.

One circumstance, however, was wanting to render the analogy between siliceous and calcareous wood complete. In that species of siliceous wood, which has been distinguished by the term opalized wood, appearances were observable, which seemed to warrant the conclusion, that some of the bituminous wood had existed, at the time of its impregnation with silex, in a softened, and, perhaps, fluid bituminous state; and that the waxy lustre, which this species of wood displays, proceeded from the intimate union of the silex and bitumen, whilst each was in a fluid state: but no analogous appearance to this had offered itself, to my observation, in any specimen of calcareous wood. It happened, however, that, a few days before this sheet was sent to the press, I met with a piece of calcareous spar, imbedded in blue lime-stone, which, at its fracture, displayed somewhat of the resinous lustre; and, on its polished surface, exhibited a beautifully clouded appearance, resembling tortoiseshell, yielding, in fact, exactly such an appearance, as might be expected, from the intermixture of petroleum and spar. By the aid of a magnifying glass, somewhat of a fibrous texture, like that of wood, was observable in the lighter-coloured parts, but not in the least in the dark, apparently bituminous parts, which had just so much transparency as to allow the transmission of light at its edges. A small portion of this spathose matter, about 50 grains, was added to an ounce and an half of diluted nitric acid. During the effervescence, several small fragments, evidently of bituminous wood, were detached; and, on the subsiding of the effervescence, these sunk to the bottom, leaving the fluid still turbid, and of a dark brown colour: but, in about twelve hours, the liquid became clear; the less completely changed wood sunk to the bottom, and a light bituminous matter swam at the top. That calcareous spar may owe its colour, in some instances, to bitumen, cannot therefore be doubted: nor do I in the least doubt but investigation will discover, that the influence of bitumen is much more extended, among the class of calcareous stones, than has been hitherto supposed.

The appearance which the above-mentioned fossil wood from Oxfordshire yielded, previous to its exposure to the action of the acid, was such as to lead me to suppose that it must have existed, in a dry and withered state, at the time of its lapideous impregnation, it being of a very pale colour, nearly resembling that of decayed wood. But, on the removal of the stony matter, by the action of the acid, it resumed the dark brown colour of bituminous wood, which it retained, after it had been dried by the fire. The light colour, which had thus deceived me, evidently proceeded from the abundance of the white, spathose matter, with which it had been penetrated; and which had been in so considerable a proportion, that, on its removal by the acid, the vegetable or bituminous matter no longer held together, but subsided in a flocculent sediment to the bottom of the vessel.

This kind of fossil wood is frequently found inclosed within the solid lime-stone; and it happens most frequently, that when sufficient carbonate, in solution, has not percolated through the coarser carbonate, or lime-stone, to impregnate the whole of the inclosed wood, the latter remains soft and yielding, and exactly like bituminous wood; and what carbonate has entered, is formed into crystalline septa, which, by intersecting each other, necessarily divide the inclosed wood into small polygenous fragments: the whole yielding an appearance, which would not be badly represented by Fig. 5. in Plate I. only substituting the brown bituminous wood, for the jet: nor would a very dissimilar idea be formed of it, by conceiving its divisions to resemble those of the Septarium, Ludus Helmontii, or Waxen Vein.

It would be improper, whilst treating of the calcareous petrifactions of vegetables, to omit noticing those of Preservation Island, in New South Wales. These are thus described by Mr. Collins, in the second volume of his account of this colony. "Amid a patch of naked sand, upon one of the highest parts of the island, at not less than 100 feet above the level of the sea, within the limits of a few hundred yards square, were, lying scattered about, a number of short broken branches of old dead trees, of from one to three inches in diameter, and seemingly of a kind similar to the large brush wood. Amid these broken branches were seen sticking up several white stony stumps, of sizes ranging between the above diameters, and in height from a foot to a foot and a half. Their peculiar form, together with a number of prongs of their own quality, projecting in different directions from around their base, and entering the ground in the manner of roots, presented themselves to the mind of an observer, with a striking resemblance to the stumps and roots of small trees. These were extremely brittle, the slightest blow with a stick, or with each other, being sufficient to break them short off; and when taken into the hand, many of them broke into pieces with their own weight. On being broken transversely, it was immediately seen, that the internal part was divided into interior or central, and exterior or cortical. The exterior part, which in different specimens occupied various proportions of the whole, resembled a fine white and soft grit-stone; but acids being applied, shewed it to be combined with a considerable portion of calcareous matter. The interior or central part was always circular, but seldom found of the same diameter, or of the same composition, on any two stumps. In some, the calcareous and sandy matter had taken such entire possession, that every fragment of the wood was completely obliterated; but yet a faint central ring remained. In others was a centre of chalk, beautifully white, that crumbled between the fingers to the finest powder: some consisted of chalk and brown earth, in various quantities and some others had retained a few frail portions of their woody fibres, the spaces between which were filled up with chalky earth." Mr. Bass, who acted as Surgeon on board the Reliance, and from whose accurate examination the above account is taken, was told, from good authority, that when the trees were in a complete state, the diameter of the dead wood of the stem, that rose immediately from the stony part, was equal to the diameter of that part; and also that a living leaf was seen upon the upper branches of one of them. Mr. Bass was induced to place these altered vegetable substances amongst petrifactions, although, he says, no strict analogy could be discovered, between them and the subjects usually met with of this kind: this gentleman acknowledging, at the same time, the great difficulty of accounting for this wonderful change which had taken place in the lower parts of the stems of these trees.

If this ingenious and intelligent observer found himself incapable of explaining the mode in which this change had been accomplished, it is not to be expected that even the attempt should be made by one not possessing the advantage of examining the substances themselves, nor of ascertaining their relative situation with the surrounding substances.

In the Philosophical Transactions is the description of a phenomenon which seems to bear some slight resemblance to that which has been just described, and which also is not capable of being explained, by any of those laws on which the various processes of petrifaction appear to depend. It is thus related:

" In a close of Mr. Purefoy, near his house, called *Wadley*, a mile from *Farringdon*, in *Berks*, there grows an elm, which hath now lost the top, and is grown hollow, containing near a ton of timber. From the but of the same tree, one of the spreading claws, having been formerly cut off with an axe; that part of the but, from whence the same was severed, being about 1¼ foot above ground, and inward within the trunk of the tree, hath contracted a petrified crust, about the thickness of a shilling, all over the woody part with the bark; the marks of the axe also remaining very conspicuous, with this petrified crust upon it. By what means it should thus happen cannot well be conceived, in regard there is no water near it, the part above the ground, and out of the weather; the tree yet growing; unless being cut at some season, when the sap was flowing, the oozing of the sap might become petrified by the air, and the tree grow rotten and hollow inward since that time; which how long since is not known.

"A piece of that part cut was presented, together with this account, to the Royal Society, for their repository*."

Aluminous fossil wood is mentioned by several authors: Mr. Walch describes it as being of a brown colour, of a light weight, and possessing sufficient of its vegetable structure to demonstrate its origin: he also relates that when considerable quantities of it are exposed to the air, that it will take fire spontaneously. Besides being found in various parts of England, it is found in considerable quantities at Commadau and Alsattel, in Bohemia; near Haitfield, in Lower Austria; at Weisner, in Hesse; and near Duben, in Saxony.

The spontaneous inflammation of this species of wood, and the use to which it is applied, the fabrication of alum, manifest that it is a pyritous wood blended with clay. The chief component parts of alum (the sulphate of alumine) are the acid of sulphur and the earth, alumine; the former of which is derived from the sulphur contained in the pyrites, and the latter from the clay, of which it constitutes by far the greatest part.

What other earths enter into the composition of fossil woods, and in what proportion, must be determined by future analyses.

Yours, &c.

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* Philosophical Transactions, N° 19, Nov. 1666.

LETTER XLI.

METALLIC FOSSIL WOOD....BOG IRON ORE....FOSSIL WOOD, IMPREGNATED WITH IRON....WITH COPPER, &C.

Besides the pyritous fossil woods, already treated of, there exists a great variety of metallized fossil woods, the particularities of which we shall now endeavour to ascertain; but which could not have been so well done, until the influence of bituminization in the petrifaction of vegetables had been displayed.

As iron is the metal which is most generally diffused in the earth, so it is also most frequently found in combination with fossil wood. The most remarkable specimens of this kind of wood have been found in Siberia, and in various parts of Germany. In the year 1710, a wonderful metamorphosis of a tree into iron ore, to use the words of the author*, was discovered in the neighbourhood of Solms Laubac. In digging a well, the workmen first found, at the depth of a few feet, an urn, from which, and some other circumstances, it was supposed to have been a spot on which the remains of the dead had been consumed. When the diggers had reached the depth of 70 feet, their progress was checked by a vast impenetrable mass, which appeared to be the trunk and branches of a large tree. Finding this mass to resist their hatchets, and other instruments, they proceeded to remove this impediment to their labours by force; breaking, but with great difficulty, the metallized tree into fragments, which they threw about, without any farther notice. Chance, however, having brought some of these fragments to the is constituted, and will be likely to deposit, in its substance, an oxide, so nearly at its *minimum* of oxidation, as to approach nigh to the hardness, gravity, and lustre of a metal. Such, indeed, appears to be the constitution of those specimens of ferruginous wood to which I here allude. That part which was originally ligneous appears to have become the most solid and metallic, whilst the cavities appear to have been filled by a rust-like precipitate. Among the boggy iron ores, are frequently found specimens which illustrate the manner, in which this kind of metallized wood is formed; and also shew that it has been by an operation carried on near the surface. In these, which are often in large masses, broken twigs of trees, grass, and other vegetable matters, are found, considerably changed, and indurated, and connected together by a fine yellow, or yellowish brown, oxide of iron. But the following account, from an intelligent observer, will serve to give you a more correct idea of the effects resulting from this important natural process.

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* J. J. Liebnecht, Discursus de Diluvio Magno, pag. 206. 1714.

Mr. Tooke remarks, that one of the principal curiosities, among the mountains of Russian Lapland, is in the martial waters of Ussona, Muun-ozero, &c.. Here are seen, he says, a vast quantity of stems, branches, twigs, leaves, and roots of birch trees, and other exuviæ of vegetables, entirely mineralized by iron, with the diverse texture of the rotten wood plainly visible; in which mineralizations the tender white rind, known to be in the highest degree incorruptible, is preserved quite in its natural appearance; the soil is changed into a rich ferruginous earth, and the grassy sod into iron ore. The like transmutations are seen in all the low spots and pits that incline towards the Muun Lake, but particularly near the Martial Waters, and over against the village Buijova. Here lies the iron ore in a wide extended valley, forested apart with birch-trees, and with gently-rising hills on both sides. In this valley, though not in its deepest bottom, issue the Martial Springs, which, in 1716, by command of Peter I. were fitted with accommodations for public use. The well is sunk about three archines and a half below the surface, in a hole in the ground, consisting of parts of roots both of trees and herbs (which are partly mineralized), and intermingled with flakes of stones, then an archine and an half in a clayey kind of stone, mixed with a great quantity of sulphur pyrites. In the deep points of the valley, under the forementioned, there is a layer of vitriolic earth, which is a mixture of iron earth and swampy iron ore (bog ore). It is easily got, and is then taken to the vitriol works, and there boiled*.

According to the degree of change which the vegetable matter has undergone, and the quantity of metal introduced, must of course its gravity vary; hence the range of variation of gravity in different specimens of fossil iron wood is very considerable. The specimens in which the change has been considerable, will in general be found to be of pretty high specific gravity. These are chiefly formed of a brown rust-like metallic substance, sometimes marked by spots of a red colour, approaching to a crimson; the form and texture of the mass readily leading to a recognizance of its original mode of existence. By far the greater part of some specimens, is evidently composed of pyrites, the rust-like substance appearing only on the surface; but in these, there is great reason to suppose, that this covering has proceeded from a partial decomposition during exposure to the air.

It is necessary to observe, that, independent of those specimens, which, from the very large proportion of iron which they contain, deserve to be distinguished as metallic, there is scarcely any specimen of fossil wood on which the indurating effects of iron does not appear to have been exerted. It is evident, that to the different precipitates of this metal, may be attributed many of the various beautiful colours which the several specimens of siliceous fossil wood are found to display.

Among the more beautiful of the fossil woods are those which owe their metallization to copper: the finest specimens of which are found in Siberia. The most accurate account of this species of fossil wood is furnished by M. l'Abbé Chappe d'Auteroche, who travelled, in the year 1761, into Siberia, where it is found in very considerable quantities, in the copper mines of the Ryphean mountains, and in the neighbourhood of Cazan. He describes different kinds of specimens. The first kind he speaks of as copper mineralized in sand and wood. In this mine he observes that blend, which he at first took for iron, is distinguishable, mixed with wood, sand, and copper. Those parts which contain the blend and the sandy part, form a very hard and compact stone; but the vegetable parts which it contains are so friable, as to be very easily detached; the copper being discoverable in large spots of a beautiful grass-green colour. The wood is black, and resembles charcoal, whose parts are united together by some tenacious matter. The copper is crystallized in many parts of the vegetable substance; its crystallizations forming small cells. These are sometimes of a clear dark or blackish green colour, and possess so much brilliancy, as to give the idea of vitreous crystallizations. The copper is blended throughout with a calcareous earth. The mine from which this mineral was obtained is to the north of Souxson.

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* View of the Russian Empire, by William Tooke, Esq. vol. i. p. 86.

Another mine, to the south of Souxson, he found differed from the one just mentioned only in being more rich, and in the sand and the blend being in a less quantity. In this mine were many parts of an azure blue, sometimes in layers, and frequently in patches. Speaking of copper mineralized in wood, he says, It may be discovered, by the specimen which I brought, that it belonged to a tree which was at least a foot in diameter. The internal part is reduced almost to charcoal, being very friable, although the parts are held together by a tenacious matter. The copper is sometimes crystallized in little cells, resembling those of an honey-comb; but these crystallizations are, in general, only among those filaments of wood which have entirely lost their original nature. The bark is distinguishable, being about four lines in thickness. There are two layers, one of which is of an azure blue, the other of a pale green, approaching to verdigris. This wood was taken from the mines in the neighbourhood of Souxsons. Mons. D'Auteroche was informed, on the spot, that they sometimes found, in the strata of these mines, entire trees. The specimens he brought home, he took from a collection which occupied the greatest part of a room, which was more than twenty feet long. This wood, he observes, contains more or less copper, according to the places where it has been found; and displayed various appearances, with respect to colour, but always possesses either green, or azure blue*.

An examination of these several species of fossil copper wood, which I am happy in possessing, shows that the impregnation is made by a carbonate of copper, which appears in several places in its most beautiful form, that of malachite. The brilliance of their colours, the completeness of the transmutation, and the perfect preservation of their original forms, place these specimens among the most beautiful and interesting of the vegetable secondary fossils. One small specimen, described at Fig. 19, in Pl. VI. is highly interesting, on another account. On its surface, the charred wood, and spots of malachite, are discernible, in several parts, whilst a transverse section shews its substance is formed of copper pyrites, of a metallic lustre, displaying, by the striæ and circles with which it is intersected, an indisputable ligneous structure.

Whilst speaking of the impregnations of fossil wood with iron, I spoke of these, which, although evidently containing that metal, did not hold it in that proportion as to admit them to be distinguished by the epithet metallic. A specimen of fossil wood, which I have lately obtained, yields a beautiful instance of this sub-impregnation with copper. The ligneous form and texture, with even the knots, are perfect. The colour in some parts differs but very little from that of decayed wood, whilst the central part demonstrates the strongest marks of its having undergone the bituminous fermentation; and the surface, tinged, more or less, of a greenish hue, is marked by a few spots of malachite: the whole demonstrating, that an impregnation, with a solution of carbonate of copper, had taken place, and had arrested the progress of the bituminizating process.

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* Voyage en Siberie, en 1761, par M. l'Abbé Chappe d'Auteroche, tome i. 2de partie, p. 671.

The combination of the other metals with fossil wood is not very frequent. Some authors, and particularly Volkman, have spoken of wood impregnated with silver. That this may have been the case is by no means improbable; at the same time, it is not to be positively concluded, that the specimens, of which they speak, were impregnated with this metal; since it is not said that they had been submitted to any chemical test; and the brilliance of some pyrites is such, that, although they do not contain the least particle of silver, they frequently exhibit the splendour, and the whiteness of that metal.

Yours, &c.

LETTER XLII.

VARIETY OF PETRIFIED WOODS....PROCEEDING FROM ORIGINAL NATURAL DIFFERENCE....FROM THE LABOURS OF MAN.

THE resemblance between the recent and fossil woods is sometimes very close, with respect to colour. The bituminous willow, found by Capt. Perry, near Dagenham-breach, he describes, as having suffered little or no alteration in its colour; and, in a specimen resembling mahogany, and in various others, now before me, there appears to be the strongest reason for supposing, that, from the absence of certain mineral or saline agents, the bitumen has retained the colour of the vegetable substance, to which it was indebted for its origin.

So perfectly do the masses of petrified wood sometimes retain the characters which belonged to them in a recent state, that it frequently happens that, although so considerably changed in their nature, it is not difficult to determine to what species of wood the petrified mass originally belonged. Thus, in Plate II. Fig. 4. and Fig. 5. is a specimen which bears an exact resemblance to a piece of deal, which, having split at one end, has had the rifts, thereby occasioned, filled up by a dark coloured bitumen, as is depicted in Fig. 4.; and which, as is shewn in the section of the same piece, at Fig. 5., has insinuated itself to a considerable depth into the substance of the wood. Volkman describes a similar specimen, as having a black crust, like resin or pitch; and which he supposes to have been the resin of the fir or pine; which had been caused thus to exude, by the influence of subterranean heat. The fir, which in a petrified state is known by the terms *Elatites*, *Peucites*, and *Lithoxylon Abietis*, is said to be found less frequently in a petrified state, than many other trees; at the same time that it has been found, in a bituminous state, much more frequently, than any other. But the supposed frequency of its occurrence, in a bituminous state, is very likely to exceed the fact; since the high degree of inflammability, which bituminous woods possess, has led to the suspicion, that all such woods, especially if their fibres ran straight, were of the fir or pine kind; their inflammability being attributed to the resin, or turpentine, which they were supposed to contain.

That they are frequently found in subterranean situations, in this island, is indubitable. Dr. Leigh, speaking of the subterranean trees found in several of the morasses in Lancashire, says*, " Not only fir-stocks, but fir-apples, are likewise found in these morasses; and these, I hope, gentlemen will allow me, could not belong to any other tree, but to the fir: besides, the grain of the wood, and the turpentine which upon burning drops from it, sufficiently demonstrate it to be really fir."

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* The Natural History of Lancashire, Cheshire, &c. by Charles Leigh, M.D. 1700, p. 69.

Mr. Daines Barrington informs us, that he happened to see, near Loch Rannoch, and in other parts of the highlands of Scotland, subterraneous firs which had been lately dug up. On cutting them he found that they smelt strongly resinous, and he concluded that there could be no doubt but that they were firs, the grain of the wood farther warranting this opinion. The poor people, he observes, in those parts, use small pieces of this wood, instead of candles. He, therefore, thinks that there is little doubt that the fir was formerly an indigenous tree, in the northern parts of this island. Dr. Plot argues, that Cæsar, not having seen the northern parts of this island, where the pines most probably grew, might easily be mistaken in that, as well as with respect to the beech, which he asserts was not in this island, though the contrary has been found to be the fact. Whilst some have relied on Cæsar's account, and have believed that at the time of his visiting this island no fir-trees grew here, others have supposed that they have been subverted, with the vast forests, which were filled by the Roman soldiery; and others report that the remains of considerable forests of this tree have been seen within the memory of man. But their subversion, most probably, took place, at an epoch much more distant than that of the invasion of this island by Julius Cæsar.

A specimen of the petrified larch-tree *(Laricites)*, from Mount Krappe, in Hungary, is represented at Pl. II. Fig. 6., purchased by Mr. Strange, from the Butean collection. Pl. II. Fig. 8. represents a specimen of petrified hazel *(Corylites)*, described, in the Butean catalogue, as from the Kiesengeberg, in Bohemia. The petrified oak *(Dryites)* is said to be very frequently found; it possesses a darker hue than the recent wood: a specimen, from the neighbourhood of Vienna, bears strong characters of its original state. The same observation applies to a specimen of the ash *(Melites)*; of the petrified alder *(Cletrites)*, from Bohemia; and of the box-tree *(Bucites)*, also from Bohemia. The fossil wood of the beech-tree *(Onytites, Syssites, vel Phegites)*, of the laurel *(Daphnites)*, of the sandal-tree *(Sandalites)*, of the willow *(Salicites)*, of the mulberry-tree *(Moricites)*, of the vine *(Vitites)*, and several others, have been described by different authors. But imagination, in many instances, has so much assisted conjecture, respecting the kind of tree from which the fossil wood has originated, that opinions respecting this circumstance should be received with caution; since very frequently the supposed resemblance is founded on colour, and on direction of fibres, which may have undergone considerable changes, and have even owed those particular appearances, to the influence of circumstances dependent on a subterranean situation. Whilst, in some, their vague and indistinct marks are insufficient to allow of any opinion being adopted, respecting their primitive form; in others, appearances offer themselves dissimilar to those of any known recent tree. The specimen at Pl. II. Fig. 3. has been supposed, by some, to be of this kind; whilst others have supposed it, from its large pores, to have belonged to some tree, allied to the cabbage-tree. The petrified wood of the linden-tree *(Philyrites)* is said to possess generally a clear white hue. Mr. Walch describes a white petrified wood found in Hungary, which he supposes may have been of this tree; but he says, that it contains a stony substance, resembling a resin; but which, he says, it cannot, however, have been, since this tree yields no resin; nor does resin, although it hardens very readily, ever petrify. Besides, he remarks, that it exceeds in quantity the remaining ligneous substance, and manifests no mark of its being of a resinous nature, even when exposed to the fire. He therefore concludes this matter must be of the nature of spar, approaching to horn-stone; but which, like all spar, does not give sparks with the steel. The substance here described, was doubtless similar to that which has been before noticed, as having been described by Mr. Walch, and as most probably being a variety of the pitch-stone, or semi-opal; and, perhaps, a combination of clear bitumen and silex. In a most beautiful specimen of fossil wood, of this kind, lately obtained from the collection of Mr. Forster, and which is more than a foot in length, and a foot and a half in circumference, almost the whole of its substance is formed of a semi-opaline substance, possessing the clear white hue, mentioned by Mr. Walch, mingled with a dark brown semi-pellucid pitch-stone: the surface only presenting the real appearance of wood, and that in a withered shivery state, but yet impregnated with silex.

Those substances which, though now in a petrified state, are supposed to have derived their forms from the art of man, previous to their undergoing the change from wood to stone, will be examined with propriety, in this place, whilst considering the varieties which occur, in petrified ligneous substances. The instances which have been given of any fossil substances which had derived their form from the labours of the inhabitants of the world, at any distant period, are remarkably few, and do, indeed, all appear under circumstances which render the actual existence of such petrifactions highly problematical.

The substances which have been most frequently mentioned, as being of this description, are those which bear the form of logs, billets, posts, and planks. But, surely, when it is considered, that a rude resemblance may have been frequently sufficient to have given rise to this opinion, and that wood, long exposed to the weather, to alternate sunshine and wet, to agitation in water, and afterwards buried by some violent convulsion, must be broken into a great variety of forms, it is not at all improbable, that it should, in some instances, assume an appearance, that might lead to the suspicion of its having been subjected to the operations of art. The same observation must apply to many of those substances which have been supposed to have been stakes, posts, and piles, which have been driven in the beds of rivers, &c. Of this description are the pieces of wood which have been frequently dragged up from the bottom of the Thames, and which have been supposed to have been placed there by the soldiers of Julius Cæsar. One of these was in the possession of the late Duchess of Portland, and was purchased at her sale, for nine guineas, by the late John Hunter, Esq. and is in the matchless museum, which, by the death of that gentleman, is now in possession of the Royal College of Surgeons of this city. An examination of this body tends to confirm my suspicion, that substances of this kind do not owe any thing of their forms to the labours of the Roman soldiers. This piece of wood, about three feet in length, the surface of which is broken into flakes, by drying, has exactly the colour, and general appearance, of bituminous wood. Now from the observations, already noticed, of Capt. John Perry, made during his labours, so ingeniously adapted to the stopping of Dagenham-breach, it is evident, that the Thames intersects a vast bed of bituminous wood (moorlog); pieces of which must be perpetually separating from the banks of the river, and falling to its bottom; and which, being repeatedly dragged up, have been supposed to have been planted there, for the purpose of facilitating the Roman army in fording this river. Indeed, wherever similar pieces of wood have been thus found, in rivers, &c. near to which history informs us Julius Cæsar has ever been, the much altered appearance of the wood seems to have led to the attributing of it to the labours of that distant period. Thus it is related, by Mr. Swinburne, that "The workmen but this last year a violent storm from the north-east laid a part of it bare; and several masses, consisting of iron, ropes, and balls, were found on the sands near the place, covered over with a very hard ochry substance, of the colour of iron, which adhered thereto so strongly, that it required great force to detach it from the fragments of the wreck. And, upon examination, this substance appeared to be sand, concreted and hardened into a kind of stone."—The specimen which was laid before the society, "contained a piece of rope, adjoining to some iron ring, and probably had been tied thereto. The substance of the rope was very little altered; but the sand was so concreted round it, as to be as hard as a bit of rock, and retained very perfectly impressions of parts of the ring, just in the same manner as impressions of extraneous fossil bodies are often found in various kinds of strata.

"Now, considering these circumstances," Mr. King says, "we may fairly conclude, in the first place, that there is on the coasts of this island, a continual progressive induration of masses of sand, and other matter, at the bottom of the ocean, somewhat in the same manner as there is at the bottom of the Adriatic sea, according to the account given by Dr. Donati.

"In the next place (which is what more particularly deserves our attention on this occasion), it should seem, that iron, and the solutions of iron, contribute very much to hasten and promote the progress of the concretion and induration of stone, whenever they meet and are united with those cementing crystalline particles, which there is reason to believe are the more immediate cause of the consolidation of all stones and marbles whatsoever, and which do very much abound in sea-water."

The same conclusion, he also thinks, may be drawn from another incrustation. "Some fishermen, sweeping for anchors in the Gull-stream (a part of the sea near the Downs), drew up a very curious old swivel gun, near eight feet in length. The barrel of the gun, which was about five feet long, was of brass; but the handle, whereby it was to be turned or traversed, which was about three feet in length, and also the swivel and pivot on which it turned, were of iron; and all round these latter, and especially about the swivel and pivot, were formed exceeding hard incrustations of sand, converted into a kind of stone, of an exceeding strong texture and firmness: whereas round the barrel of the gun, except where it was near adjoining to the iron, there were no such incrustations at all. The incrustation round the iron part of this gun was also the more deserving of attention, because it inclosed within it, and also held fast adhering to it on the outside, a number of shells and coralline, just in the same manner as they are often found in a fossil state; much resembling in colour and appearance some of the masses of fossil bodies found near Chippenham, in Wiltshire.—It is to be observed, notwithstanding the iron was, by some means or other, the cause of this induration, it was very little dissolved, although the gun must have remained in the sea above 200 years, and probably a good deal longer.

" Dr. Fothergill, on passing through the streets of London in his walks, before the sign-irons were taken down, he perceived that, on the broad stone pavements, whenever he came just under any of the sign-irons, his cane gave a different sound, and occasioned a different kind of resistance to the hand, from what it did elsewhere; and, attending more particularly to this circumstance, he found, that every where, under the drip of those irons, the stones had acquired a greater degree of solidity, and a wonderful hardness, so as to resist any ordinary tool; and gave, when struck upon, a metallic sound: and this fact, by repeated observations, he was at length most thoroughly convinced of. This observation of the Doctor's was illustrated by some experiments, in which he ascertained, that, by thus washing frequently pieces of Portland-stone with water impregnated with rusty iron, they acquired a very sensible degree of the hardness here described, and on being struck gave the metallic sound.—Part of an horse-shoe was seen by the Doctor, on the sea-coast, near Scarborough, incrusted with sea-sand; and, although the sand was but little tinctured with an ochry colour from the iron, it had acquired the hardness of common grit-stone."

Part of a ladder, with some of the steps, which Mr. Baillou, of Florence, presented to the Emperor, and which was placed in the Imperial Museum at Vienna, was most probably merely an incrustation; similar incrustations of ladders, &c. frequently occurring at the incrustating springs in this kingdom: and Italy, from whence it appears this cabinet specimen was sent, as we have already seen, abounds with waters, possessing this quality. Neikel relates that they used *formerly* to shew a plate originally wood, but one half of which was changed to stone. But it should be considered, that *formerly*, also, the arrow-heads and stone hatchets of the aborigines of some parts of Germany, not very dissimilar from those we now receive from the South Seas, were regarded as thunderbolts. Thus Lachmund says, the names of *CERAUNIA*, *Ceraunius Lapis*, *Donnerstein*, and *Donnerkeil*, were given to those stones which had fallen from the clouds at the time of thunder, and which resemble hammers, hatchets, wedges, &c. being perforated in the thicker part. He particularly mentions one, which, he says, had been driven, by the force of the thunder, twelve ells deep in the ground, in a wine-cellar; another, which had split a large oak, near Ileburg; and another, which had been struck into a tree, by the power of the thunder, in a field near Torga*. Thus also Wagner and Lang† place the stony dice, *TESSERÆ LUSORIÆ FOSSILES LAPIDEÆ*, among the petrified figured stones assuming a regular form. These little white cubic, and exactly marked stones, they describe as being

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* Oryctographia Hildesheimensis, à D. Friderico Lachmund. 1659.

† Historia Natural. Helvet. fol. 329. Historia Lapidum Figuratorum Helvetia Caroli Nicolai Langii, p. 68.

[illegible] [illegible] more [illegible], than the substances to which the [illegible] [illegible] is chiefly appropriated, the [illegible] [illegible] (Chal-cedony or [illegible].

These stones, representations of which will be found in Pl. VII. Fig. 1, 2, 3, &c. are chiefly found in the neighbourhood of Chemnitz, and particularly near to Hilbersdorf. Specimens of this kind of stone have been said to have been also found near Belgrade; and, in particular, one specimen has been mentioned, which was supposed to be one of the piles belonging to the bridge, which the Romans had erected over the Danube. The general appearance of most specimens of this stone conveys the idea of its being fossil wood; but those marks which dispose to this opinion, although evident in some, are, however, hardly, if at all, discoverable in others. The hardness of these stones, in general, appears to be nearly that of jasper, whilst in others it even seems to approach to that of agate. The general colour of their ground is mostly of a dark brown, sometimes inclining to a brick-dust red; but, in different specimens, most of the common colours of fossil wood will be found to form that of their several grounds. The circumstances, however, which constitute the difference between these substances and all the other different species of fossil wood, are the appearance of oval or circular spots, from the size of a crow-quill to that of a goose-quill, filled with a substance generally of a more crystalline appearance, and of a different colour from the ground. The substances with which these spots are filled, are sometimes evidently calcedonic; sometimes they resemble cornelian; and sometimes they are complete onachyne agate. The margins of these spots are, commonly, well defined, by a circular or oval line: in some instances this line is hardly perceivable, but in others it is so thick, that, being continued through the substance of the stone, it forms a perfect tubule. In the centre of these spots may be mostly discovered starred bodies, differing in colour from the rest of the spot: the stars varying in the number of their rays; some having only four, whilst others have five, six, seven, and even eight rays. These stellated bodies pass through the substance of the stone, so that the same star will be seen on the upper as on the under side. The variegated surface of these stones gives them a very curious appearance: the spots, which are of various colours, red, brown, bluish white, &c. are generally quite distinguishable from the ground; whilst the central star is also, frequently, plainly distinguishable, from its differing again from the colour of the spot which surrounds it. Thus a most pleasing mottled surface is formed, such as cannot be described, and such as cannot well be copied by art.

No inquiries which have been made, respecting these stellated substances, have as yet terminated satisfactorily. Mr. Walch observes, that, in some of these stones, their ligneous origin is rendered indubitable; the fibres of the wood being discoverable in the transverse, as well as in the longitudinal section of the fibres; whilst in others, he allows, it is by no means evident. But, as he remarks, the grand difficulty exists in determining the nature of those substances which assume this stellated form, and which possess colours so various, and so different from those of the other parts of the stone. Some, with Mr. Schultz, have been decidedly of opinion, that these stellated appearances proceeded from the filling up of the natural pores of the wood, by the infiltration of a stony matter; the wood being of some exotic, and unknown kind of tree, whose pores were of a stellated form. Some have attributed the tubular part to the labour of some insect of the tubularia or teredo kind; and which they have imagined has been afterwards selected, by some zoophyte, for its habitation; whilst others have conceived, that the tube, as well as the star-like figure, were both attributable to the same zoophyte. M. Genzmer was of opinion, that these curiously formed bodies were originally a species of stellated coral. Mr. Walch, finding a closer resemblance between these bodies, and the pentagonal stalks of the encrinus, concludes them to have been a species of cartilaginous zoophytes. Mr. Schultz, by cutting a stone containing these substances, in various directions, ascertained that they are continued columnar bodies, some of which, he says, are angular, others cylindrical, and some pyramidal. That they have been a species of columnar asteriæ, he thinks, is proved by their longitudinal section displaying striæ of two or three colours; the colour of the stone, for instance, appearing in a dark line, with a red or whitish line on each side of it, formed by two projecting rays.

Anxious to form a correct judgment respecting these bodies, I have eagerly furnished myself with every specimen of the kind within my reach; and, imitating the labours of Mr. Schultz, have obtained sections of these bodies in almost every direction: but, as you will perceive, without obtaining much positive information respecting them. With respect to the first-mentioned opinion, that of these stellated forms being derived from the natural pores of the wood, I have to remark, that they are seen in three states, so widely different, as could not at all accord with this opinion. In the one, the stars exist without any surrounding containing ring; in another, as in Pl. VIII. Fig. 1. they are surrounded by circular, or somewhat oval lines, which have the appearance of the section of the longitudinal vessels of the plant, but uncommonly large; and in another, they are surrounded by a ring, as at Fig. 3., which there seems no difficulty in considering, as the tube formed by the teredo navalis, or some such insect. This want of uniformity, therefore, takes away much from the probability of their form depending on the natural pores of a plant.

The opinion of their having been coralline bodies, is opposed by the material difference observable in their internal structure. In corals, indeed, there is somewhat of a stellated appearance, formed by very fine lamellæ passing from the centre to the circumference, the intervening parts bearing rather the appearance of the petals of a flower with the points towards the centre; the reverse of which is the appearance which is yielded by these stars, the rays or points all tending outwards. Two very forcible objections exist against their being, as some have supposed, the stalks of pentacrinites, or the plumose encrinus; in the first place, the stalks of the plumose encrinus are so generally pentagonal, that, perhaps, not one deviation will be found in ten thousand of their joints; whereas the rays of these stellæ are so inconstant in their number, that on one specimen of this fossil, of the size of the palm of the hand, may be seen several of five, and of eight, and of every intermediate number of rays. In the second place, these stellated bodies are perfectly continuous in their length, whereas the stalk of the encrinus is divided into joints, at less than each quarter of an inch. In opposition to the opinion of the surrounding ring, as well as the star, being the work of a zoophyte, must be placed the undoubted fact of the stellated column, being sometimes found in a tube, evidently the work of the teredo, or some similar insect.

From all these considerations, I am induced to conclude—that these bodies do not assume their form from any natural pores of the wood—that they are not coralline bodies—that they are not stalks of pentacrinites—and that the surrounding ring has not, in every case, been derived from the same origin as the contained column. Thus much, I trust, may be asserted, with respect to what these bodies are not; but as to any opinion, as to what they really may have been, the doubts under which such opinions have been formed, require that I should deliver myself with hesitation. There appears to be every reason to conclude, with Mr. Walch and others, that this columnar body was originally a zoophyte; totally different from any which are now known to exist, and in very few respects, indeed, analogous with any of those which we see in a fossil state.

It also appears, that one of the habitudes of this insect was that of forming a tube, for its domicile, in any appropriate substance; and that decayed wood was most frequently, if not always, selected by it for this purpose.

No section or specimen, which I have yet seen, allows us to determine whether the complete animal was in one continuous straight columnar body, or whether it separated into ramifications: nor can it be ascertained, by any specimens I have examined, what is the natural termination of the ends of this substance; no change of its columnar form having been yet seen, which would authorise the suspicion of its divaricating, and forming a head in the manner of the encrinus.

Plate VII. Fig. 1. represents a specimen which gives a very favourable view of the general appearance which this stone yields: it is not, however, so rich in colour, as some specimens are. On the lower edge very plain traces of its ligneous origin may be perceived, and towards the other edge may be seen several of the stellated bodies in the tubules, to which some are attached at one side, whilst others are exactly in the centre; the other part of the tubule being in some entirely empty, and in others either in part or completely filled by siliceous crystals.

Plate VII. Fig. 2. is a view of one of the sides of the above specimen, which possesses a striated and variegated appearance, from its shewing the perpendicular section of the tubuli, the contained starred body, and the fossil wood which is interposed between the tubuli. A careful examination shews that the stellated bodies themselves are in this direction striated. Fig. 3. represents a specimen in which the marks of wood are very decided. The tubules in this specimen have every appearance of having been formed by teredines: possessing, in general, the same size and form with those which are produced by this animal; and being also lined with a similar coating. The substance filling the tubules is constantly siliceous; and sometimes, and particularly in this specimen, it is perfect agate, in some parts of a reddish, and in others of a bluish white: the stellated body being frequently to be seen, either in the centre, or at the side of the agate. Fig. 5, 6, and 7, represent these stellated bodies, with their surrounding tubules magnified to about five times their natural size. When magnified to this degree, their substance is discovered to be intersected by several curved lines, which doubtlessly formed the canals through which the fluids of the living animal passed; but the spaces of which being now filled with siliceous matter, an appearance is yielded very much resembling the plates forming the exterior part of some echini and asteriæ.

As the animal nature of these bodies can hardly be doubted, their examination in this department of our inquiry seems to be hardly admissible; but as by far the greater number of the specimens in which they are contained, are evidently of vegetable origin; and as all the specimens which I have seen may be considered as varieties of fossil wood, differing from other fossil wood, only by the accident of the introduction of this particular substance, these observations may be, perhaps, introduced here, without any considerable impropriety.

Influenced by almost similar reasons, I shall here introduce some remarks on that fossil wood, which is so frequently found on the shore of Essex, as well as on the opposite shores, which, being hollowed out into tubular cavities, apparently by the labours of the teredo, has been distinguished by the name of Lapis Syringoides.

Representations of specimens of this stone are exhibited at Plate VIII. Fig. 8, 9, 10, where the devastating labours of this animal are sufficiently apparent.

It may not be amiss to remind you, that, from the time of Theophrastus, the lignivorous powers of this creature have been known and dreaded. Linnæus describes it as a *terebella*, possessing two calcareous hemispheres for cutting out, and two for piercing; its round bending shell piercing into the wood. Dr. Baster describes its head as being of a most wonderful structure, being covered with two hard shell-like hemicrania; but of a substance, in reality, neither osseous nor testaceous. These hemicrania, which are whiter than the rest of their bodies, he speaks of as exceeding in hardness the testaceous tube they inhabit: their inner surface, he describes, as being hollow and smooth; and the outer, convex and rough, having three ranges of fibres, passing in different directions. These two hemicrania, which are connected by strong ligaments, and, as it were, by a small hinge, by which they are able to dilate, without separating, besides defending the soft head, are the instruments by which the animal procures its food: since being placed in a manner similar to a double bit of that kind of borer we call an augur, whichever way the head is turned, the raised and rough fibres, either of one direction, or of the other, rub off some of the particles of the wood[*].

In the year 1730, the persons appointed to take care of the dykes on the coasts of Holland and Zealand, observed that the piles made of even the hardest oak, and placed for the purpose of defending the coasts of the Netherlands against the sea, were eaten through, in a few months; and so weakened, as to be broken by the slightest force. Surprised at this alarming phenomenon, they inquired into its cause, and found that, by the astonishing increase in the number of these animals, the inhabitants were threatened with the greatest danger. To this alarm we owe the account given by Dr. Baster; the inquiries of Dr. Massuet[†]; and the diffuse and elaborate, but truly learned work of Sellius[‡].

That the fossil remains of wood, here depicted, have derived their present appearance from the devastation of these same creatures, there is very little reason to doubt; since we find in them most of those characteristics of the testaceous habitation of the teredo, which Sellius has so accurately described. We here see the external small opening, dilating as it penetrates the substance of the wood—the same testaceous tube, its external surface bearing somewhat of an annular appearance; whilst its internal part presents a finely polished surface, except where invested with lapideous matter; and, in one specimen, the hard testaceous cutting hemispheres may be seen, left in the wood, which they have been excavating, and petrified with it. In these specimens we also discover the frequent close neighbourhood of the different dwellings of these animals; and remark, with admiration, the care and wonderful contrivance by which they have guided themselves, so that they should not render inconvenience to each other; reminding us, that

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[*] Philosophical Transactions, Vol. XLI. Part I. No. 455.

[†] Recherches interessantes l'Origine, &c. des diverses Especes de Vers, à Turgeau.

[‡] Historia Naturalis Teredinis Marinæ.

——— parcit
Cognatis maculis similis fera.

Thus we rarely see an instance of their at all invading each other's premises, whilst pursuing their frequently tortuous passage; but each one pursues its allotted path and operations; and, like the locusts, as mentioned by the prophet Joel (chap. ii. v. 7, 8.), so aptly quoted by Sellius, "They march every one on his ways, and they break not their ranks; neither does one thrust another, they walk every one in his path." This curious circumstance will appear evidently on a view of Pl. VIII. Fig. 9.

As in the ordinary fossil wood we have perceived that its lapideous impregnation may be either effected by the introduction of lime, silex, or alumine, so also, in this variety of fossil wood, similar impregnations are met with. In Pl. VIII. Fig. 8. is represented a most beautiful specimen of silicized bituminous wood, in which the ravages of the teredo are very manifest. In this specimen, the filtrated siliceous matter, having acquired a strong brown or yellowish tinge, perhaps from the admixture of fluid bitumen, fills up one of the cavities, left by the worm, with a transparent topazine calcedony, giving an appearance exactly resembling that of the *larva* of some insect. Its other cavities are filled with a substance so strictly agatine, as to possess not only the colours, but even the lines, which characterize that species of agate called the fortification agate. Fig. 10. of the same Plate represents a piece of silicized wood, which has the appearance of having suffered but little change from bituminization; having rather the appearance of a dry withered wood. In this specimen the cavities formed by the teredo are uniformly filled by a white pellucid calcedony, apparently free from any foreign intermixture. Fig. 9. of the same Plate is from a specimen which is impregnated with carbonate of lime, which, in a spathose state, has filled several of the tubes formed by the teredo, and invested the internal surface of others. Frequently particles of pyrites may be seen intermingled with the calcareous spar; and frequently also will the wood be so permeated by clay, as to allow it to be termed aluminous wood; employing the term in that loose sense, in which it has been already applied to fossil wood, into the interstices of which clay has freely penetrated.

On putting a piece of this wood, impregnated with lime, into diluted nitric acid, the same effects were produced as when other calcareous fossil wood was subjected to the same experiment. The carbonate of lime was decomposed, and, on the earth being removed, the fibres of the wood were found in a loose and detached state; of a dark brown colour, and burning with a white flame, and a bituminous odour, on being applied to the flame of a candle.

I have, in a former Letter, remarked that the process of bituminization seems to be inimical to animal life; and that, after any vegetable substance has been exposed to its influence, it appears to be no longer fitted to become the aliment of any animal. Nature having now destined this matter to undergo a peculiar chemical change, the first step is to prevent its being subject to any other kind of alteration, which might interfere with this arrangement. Agreeable to this opinion, it appears to be right to conclude, that the wood in these specimens has been exposed to the process of bituminization, since it had been subjected to the ravages of the teredines. These pieces of wood, I, therefore, conjecture to have lain in the sea, subjected to the devastating labours of these animals, until, by some of those changes of which a former Letter has aimed to give, at least, some slight notion, they became overwhelmed with earth; and that, whilst thus buried, and secluded from the atmosphere, they passed into the bituminous fermentation; and afterwards, from the infiltration of certain lapidific juices, obtained their present mode of existence.

Mr. Walch observes, that it is very rare to find shells, or the remains of any marine animals, among mineralized wood. He knows, he says, of very few instances indeed*. Scheuchzer describes a specimen of fossil wood, to which is also affixed a fossil oyster†. Davila also describes a piece of fossil wood to which an ammonite adhered. I have in my possession a very beautiful specimen of fossil wood, imbedded in a piece of the rock from Charmouth, in which is also fixed a very perfect spathose ammonite, and other specimens in which *ostreites* are thus attached. But the fact appears to be really this, that this junction of animal, with vegetable substances, in a fossil state, is only rare in those fossils which are actually siliceous.

Yours, &c.

* Recueil des Monumens des Catastrophes, &c. tom. iii. p. 30.

† Oryctogr. Helvet. p. 240.

LETTER XLIV.

SECONDARY VEGETABLE FOSSILS....IN SCHISTI....IN SAND-STONE ....IN CALCAREOUS STRATA....IN ARGILLACEOUS NODULES.

It gives me much pleasure to learn, that you purpose to extend your tour into Wales. The visiting of Dorsetshire, Devonshire, Somersetshire, and Gloucestershire, those vast mines of secondary fossils, and the traversing of Wales, with that pleasing and instructive companion, Aikin's Tour, in my hand, are among those thoughts which frequently arise, but which, hope, reluctantly, refusing to cherish, perish even, perhaps, the moment they are formed. How delighted should I be to view the wild Cambrian scenes, and to trace the mountainous bottom of the antediluvian waters! Nor should I be less pleased at viewing the various specimens of coal-slates, impressed with vegetable forms, which you will there find in great abundance. These you will frequently perceive to be so perfect, that our sceptical friend Wilton will no longer be able to hold out: he must, at last, give up the opinion, to which he has so long, and so pertinaciously, adhered, that these are the productions of the wanton and fanciful sports of nature; and must admit them to have derived their forms from antediluvian vegetable remains. With the hope of securing a convert, and of augmenting the pleasure which you must all experience, in the contemplation of these wonders of nature, I shall, in this Letter, offer you a few observations on their origin and formation.

In most of the strata which are found immediately above coal, decided marks and impressions of vegetables may be discovered: but it seldom happens, that any traces appear on the strata, on which the coal lays. A considerable difference also exists, between the several kinds of strata which lay immediately above coal, as to the quantity of vegetables they contain, and the state in which they are found. The strata which, most commonly, form the matrices of these vegetable remains, are of the schistose kind; sometimes of a bluish grey colour, nearly verging on black; sometimes of a dark brown; but most frequently of a jet black. In these schisti, the impressions are often disposed as smooth and flat, as if the plants had been carefully placed between the leaves of an *herbarium.* Where this is the case, and the vegetable remains thus form a separating medium of considerable extent between the laminæ of the schist, the complete separation of these laminæ is easily effected, by a small well-directed force; and the impressions of the vegetables are thereby clearly displayed.

The most beautiful specimens of this kind, perhaps, in the world, are those which are in that superb collection forming the Leverian museum, now the property of —— Parkinson, Esq. These specimens are almost all from the coal-pits of Lancashire, and appear to be similar to some which are described by Dr. Woodward as obtained from the Canel coal-pits, near Haigh, Lancashire. The colliers there, he says, call the substance on which they are formed *black-baft:* the colliers about Newcastle and Durham call it *plate.* The stratum of this is about a yard thick, lying 120 feet deep, and 30 feet above the Canel-coal. One specimen he describes as a black slaty coal, marked in a quincunx manner, &c. much like what might have been made by the bark of common fir. Another he describes as having the appearance of long striated leaves, having the appearance of joints, &c. upon a dark grey slaty stone. The stratum of this, he says, lay at the depth of 25 fathoms, in Bransty-cliff, by the Duke of Somerset's salt-pans, near Whitehaven. The stratum, he says, was about a foot and a half thick; and, upon the breaking the stone, leaves of plants appeared very thick in all parts of it, where the grain of the stone was thus fine and dense. But where it happened to be more gritty, coarse, and lax, there was not one leaf to be met with*. Specimens of schisti thus bearing impressions of vegetables are displayed Plate I. Fig. 6. and 7.; Plate IV. Fig. 6. and 7.; Plate V. Fig. 1, 2, 3, 6, 7, 8, 9.

The impressions of leaves are much more rarely discovered in the sand-stone strata, and are traced with much more difficulty; owing in part to the uncertain direction, in which these stones often split; and, in part, to the leaves being twisted, and to their laying in a confused and irregular direction: hence the leaf is generally divided with the stone, and its edge, or section, only exposed. Sometimes, however, a very fair impression of a leaf may be seen, on sand-stone; but it will be found, in general, to differ very much in some respects from the impressions on the argillaceous schists. Plate V. Fig. 4. and Plate III. Fig. 3, 4, and 5. represent the impression of vegetables on different kinds of sand-stone.

The occurrence of vegetable remains in lime-stone strata is undoubtedly much more rare than in the argillaceous, or schisti. Schultzen suspects some error in those accounts which state their having been observed; and Mr. Walch, who entertains the same suspicions with Schultzen, accounts for the rarity of their being met with in lime-stone, or marble, to the calcareous mountains having been formed at the bottom of the sea, where vegetable matter would be least likely to accumulate: but that they do occur in lime-stone strata is indubitable.

The remains and the impressions of leaves of trees are frequently found in the fissile calcareous stone of Oeningen, and in the calcareous stones of other parts: some of these may, perhaps, with propriety, be supposed to owe their present situation, to the effects of the general deluge; but others, especially those which are found in stones, apparently of a tufaceous origin, have been thus entombed, at a much later period. Indeed it is rather to be expected, from the frequent falling of leaves on the soft margaceous, or tufaceous matter, on the borders of lakes and rivers, that instances of such preservation of their remains should be frequently met with: which is the case in many places in Germany and Italy, as well as in several other parts of the world.

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* Catalogue of English Fossils in the Collection of J. Woodward, M.D. Part II. p. 16.

Rounded nodules of argillaceous iron frequently contain in their centre the remains of plants, the forms of which are preserved in a state of wonderful perfection. The most particular account of these substances has been given by Dr. Woodward; and, as it appears to have been the result of his own observations, I have here transcribed it. "These nodules, with leaves in them, are called *Cat-heads*, and seem to consist of a sort of iron-stone, not unlike that which is found very plentifully at Robinhood's-bay, in Yorkshire, and in the rocks near Whitehaven, in Cumberland; where they call 'em *Cat-scaups*, and are frequently melted with the softer iron ores. These, perhaps, differ not much from those described by Dr. Lister, *de Font. Med.* by the name, as I remember, of *Minerœ Ferri Pilœformis*, called *Ball-mine* in Staffordshire. These cat-heads are found only at Kenton, which is about two miles to the northward of Newcastle; and Newbiggin, about a mile to the westward of Kenton. Those of Kenton attend the stratum of coal; but lie in a bed of blue chiver, about a fathom thick, and have another stratum of black chiver of the same thickness lying under them. They are generally about six or seven fathom from the coal. Those of Newbiggin are but three fathom above the coal. They have not always leaves in them; indeed, not above one in five or six. When fresh taken forth, they break difficultly and irregularly; but when exposed awhile to the air, they split easily, and part at the leaves. They are of several sizes, from the bigness of a walnut to that of a man's fist. They are found pretty plentifully; and at about the depth of 40 fathom*."

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* Catalogue of English Fossils, Part II. p. 14.

The specimens depicted at Pl. I. Fig. 8., Pl. III. Fig. 6., Pl. IV. Fig. 1, 2, 3, 4, Pl. V. Fig. 5, 6, 10, 11, are all of this kind. These specimens are, however, not confined, as appears by Dr. Woodward's account, to the neighbourhood of Newcastle; being also found in Derbyshire, and in Wales; and, I conjecture, in most places where masses of iron-stone accompany coal.

The only specimens in which I have seen the impressions of leaves in siliceous stones, are such pebbles as are figured at Pl. III. Fig. 7. which are frequently found in various parts of England. The pebble appears to have been partly inveloped, whilst in a soft state, in a piece of a leaf, by which it has acquired the marks which it bears on its surface.

Yours, &c.

LETTER XLV.

GREAT DIFFICULTY OF ASCERTAINING EVEN THE GENERA OF THE PLANTS WHICH ARE THUS PRESERVED.—DORSIFEROUS PLANTS AND CACTI MOST COMMON.

Aware of the difficulty of determining, from little more than the outlines of a leaf, the species, or even genus, of the plant to which it belonged; and also well knowing that the greater part of the remains of plants, thus preserved, have been acknowledged to have belonged to plants not known to botanists; I anxiously sought, and was happy in obtaining, the aid of a gentleman* whose general botanical knowledge has given him high rank among the disciples of Linnæus; and whose particular knowledge, respecting the dorsiferous plants, would stamp considerable authority on any opinion he should offer respecting this order, which comprehends by far the greatest number of the objects of our present inquiry. But, though possessing all the knowledge within the reach of an European botanist, the close examination which he kindly made of the vegetable remains depicted in Pl. IV. and V. would only allow him to give an opinion, far from decided, on very few of them. These fossil remains of vegetables are, he observes, a sort of botanical riddles; and, with respect to those which appear to be ferns, the difficulty of determining to what species the several impressions may be referred, is augmented by there being so many things which they may be, and so many things which they nearly resemble, without being the same. Of the figures represented in Pl. IV. he was of opinion, that Fig. 1, 2. seemed to be a *Pteris;* Fig. 5. could not be safely referred to any known species—but was most like a *Dicksonia.* Of Fig. 6. he observed, it might be an *Osmunda;* but acknowledged that he knew nothing like it. Fig. 7. he observed, had the habit of a *Polypodium.* Of the Figures in Pl. V. he was of opinion, that Fig. 2. was probably an *Adiantum;* and that Fig. 6. and Fig. 9. were species of *Polypodium:* he also conjectured that they were all foreign, and productions of a warm climate.

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* Dr. James Edward Smith, President of the Linnean Society, &c.

I cannot thus pass this kind communication, without more particularly pointing out to you, that the paucity of the information thus gained results, not from want of kind exertions of those powers of investigation, which this distinguished botanist possesses; but from the absolute impossibility, at present, of farther removing the veil of mystery which time has placed over these substances. In confirmation of this opinion it must be mentioned to you, that Dr. Woodward joined to his own, the judgment of four gentlemen, eminent for their knowledge in botany, Dr. Plukenet, Mr. Stonestreet, Mr. Buddle, and Mr. Doody, for the purpose of examining that class of his specimens, which contained the leaves of plants.

depicted, in other respects also. The stone, which came from Silesia, is of a margaceous kind, and of an ash colour, tinged with iron; the plant itself being dark. The specimen of Scheuchzer was also obtained from a coal-mine, at Altwasser, in Silesia.

The appearance of the specimen Pl. III. Fig. 3., and which is represented with the strictest fidelity, is exceedingly uncommon. The matrix is a fine grained sand-stone; and the vegetable form which it bears is produced, merely, by a very superficial stain of bitumen. Fig. 6. of the same Plate displays a fossil frequently found in the iron-stone of Coalbrook-dale, of Derbyshire, &c. In the centre may be discerned a stalk, with a reticulated, or rather imbricated, surface, from which seem to proceed a considerable number of thin, narrow leaves, by which it has been surrounded. Its resemblance to any known plant is not sufficient to have allowed any one to point out, with any confidence, the plant of which it may have been a part. Scheuchzer thought it most resembled "Equisetum, adhuc tenellum, in densam foliorum spicam, congestum; vel spica plantæ alicujus hactenus ignota." Walch imagined it to bear some analogy with the Myriophyllon, Linnæi. Perhaps, he says, it may be Millefolium aquaticum, flosculis ad foliorum nodos. The stalk, however, which, if not imbricated, has a regular reticulated surface, proves it not to belong to either genus. The ingenious Mr. Martin, in his descriptions of the petrifactions of Derbyshire, considers this fossil as the stalk or stem of some lost, or, at least, unknown vegetable, somewhat resembling a cone of the fir-tree.

The fragments contained in the nodule Fig. 3. and 4. are not sufficiently perfect to lead to any conjecture, as to the plant to which they belong. They, however, serve, with Fig. 1. and 2., already described, to illustrate the circumstance of the two surfaces of the divided nodule representing the same side of the leaf, as will be attempted to be explained in our next Letter.

A similar specimen with that represented Pl. V. Fig. 3. has also been depicted by Volkman, from a schist from Silesia, whence this specimen was also said to have been obtained. He describes it as Rubia sylvestris, or molluga montana; Gallium album latifolium, Casp. Bauhin; Gallium album, Tournefortii. Mr. Walch states it to have been the opinion of M. Gunther, that it is the Rubia parva, flore cæruleo, cauliculos per terram spargens, Joh. Bauhini. Lhwyd has also figured it, Tab. V. Fig. 202., and describes it as Rubeola mineralis, a fodinis Actonensibus, p. 12. Fig. 7. of the same Plate seems to represent a part of the same plant, in an erect position, manifesting it to be one of the *verticillatæ*; and, perhaps, also shewing, that the *verticilli* are nearer to each other, than in the plants with which it has been compared. This specimen is an iron-stone, the fractured surface being of a rusty colour. Fig. 4. of the same Plate is a micaceous sand-stone, bearing a delicate, but very perfect and beautiful impression of a leaf, which, bearing no peculiar characteristic marks, cannot be referred to any particular plant. Fig. 5. of the same Plate represents the leaf of some plant, entirely unknown, in an iron-stone nodule. The kind represented Fig. 9. of the same Plate, on a coal schist from Wales, very much resembles the specimen figured Tab. III. Fig. 7. of Scheuchzer's Diluvian Herbarium, p. 19.; of which he says, " haud abludit Filix non ramosa major, pinnulis longis angustis, profunde dentatis, suprema pinna longius mucronata." Pluk. Amalth. Botan. p. 93. tab. 406. Fig. 10. is the remains, little more than the stalk appearing, of, perhaps, an Equisetum, in an iron-stone, of a red colour, from Coalbrook-dale, in Shropshire. Fig. 11. is also from Coalbrook-dale, and is in an iron-stone of the same colour with the former. It contains a plant probably of the same genus also: the fossil described by Lhwyd, at No. 202, approaches near to it. This he describes as Aparinæ densius foliatæ æmulum Lithophyton radiosum. E fodinis Glamorgensis. The plants in both these specimens appear to be unnaturally contracted or shrunk. Whether this appearance proceeds from the direction in which the leaves are placed, presenting little more than their edges, I cannot determine: both specimens, however, may owe their colour to the action of fire, to which they may have been exposed. Fig. 8. of the same Plate represents one of these impressions of schisti, already mentioned, as described by Dr. Woodward, from the coal mines of Haigh, in Lancashire.

Mr. Da Costa, in a paper on the impressions of plants, on the slates of coals *(schistus terrestris niger carbonarius)*, found immediately on the coal stratum, not only of this kingdom, but in France, Saxony, Bohemia, Silesia, &c. conjectures that they are impressions, and parts of different species of pines, of the tithymals, the cereus's, &c.; of large reeds, and of some arborescent plants. His account is accompanied by engravings, the descriptions of which are necessarily very short. His first figure is of an impression of a plant with rhomboidal work on it, with which three long narrow leaves were found, which appeared to belong to it. This specimen was from Oswestry, in Shropshire; a similar figure is given by Volckman, in his Silesia Subterranea, Tab. XXII. Fig. 2.; and it seems to resemble that described in Dr. Woodward's Catalogue, B. 107, q. 22. q. 32. p. 106. The second and fourth seem to be of the reed kind, having knobs placed in rows on their surface, like the vesicles of some species of the rushes. This specimen seems to have been similar to one described by Dr. Woodward, B. a. 1. p. 9. The third impression he supposes to have derived its figure from some plant of the fir kind. The fifth specimen is from Mostyn colliery, Flintshire: its surface, when attentively viewed, exhibits a reticular impression of mesh-work, or rhomboidal hollows; the sides of the rhombs, or the net-work, being raised in relief. In Pl. I. Fig. 6. you will find the representation of a similar specimen from France:

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[*] Philosophical Transactions, Vol. L. Part I. p. 228.

and serves as an instance of the peculiarity of surface these impressions frequently possess. The appearance here so varying, with the change of light, as hardly to admit a fair representation of the proteal surface; the artist, with every exertion, not having been able to succeed to his wish in this respect; since although in some points of view the rhomboidal form would appear, in most others the transition into somewhat of an oval appearance would be discoverable. In the centre of these projecting bodies, small holes are observable, being such as might be expected for the insertion of setæ, or of setaceous leaves. In the sixth of Mr. Da Costa's specimens, studs, apparently also for the insertion of setæ, are regularly disposed in the wider and almost oval interstices between the nearly semicircular receding waves of undulating lines. This form, so difficult to describe correctly, is well represented in the third number of Mr. Martin's Derbyshire Petrifactions. It is also to be seen in Volckman's Silesia Subterranea.

Plate III. Tab. IV. Fig. 9., Mr. Da Costa's sixth figure, you will find is very successfully represented in Plate V. No. 8. A careful examination of the specimen from which this figure was drawn, furnishes some information respecting the nature and the formation of these fossils. This specimen, which is not quite half an inch in thickness, bears a similar impression on each side; and having been purposely placed in water, and allowed to remain there about two hours, became very soft and friable: the internal part becoming resolved into a pulpy mass, which had evidently been formed of a confused heap of grass, and other vegetable matters, intermixed with dark argillaceous earth. The external part appearing to have been the epidermis of some species of the cactus: the internal succulent part having been washed away, and its place supplied by these foreign matters, which have become inclosed in it, and have prevented its sides from having quite collapsed together. Thus may we account for the different degrees of thickness which these

fossils possess: this depending partly on their original form, and partly on the distance at which the outer coat has been kept, during the resolution of their internal substance. The form of these fossils may depend also on another circumstance. The plant being buried in a soft margaceous mass, its external coat may remain attached to the inside of the mould, which it had formed, whilst the cavity, left by the resolution of its internal succulent part, would gradually be filled up by the introduction of earthy matter. The cortical part, thus inclosed in earthy matter, would undergo the bituminous change; and the bitumen, thus filling up the impressions in the mould, which the external surface had formed, would present the exact figure of the original surface. That such a change has been produced, and that the cortical part of these plants was much thicker than any of the succulent plants now known, is evinced in numerous specimens. So different, indeed, do these plants appear to have been from any vegetable now known, as to give full reason for supposing them to have belonged to a tribe entirely lost.

Every oryctologist is aware of the difficulty of giving names to fossil plants, each schistous stratum being an immense herbarium, of which every separated schist is a folio, on which are depicted the figures of plants of the old world: most of which no longer exist, or if they do, it is in countries so distant, as to leave us seldom any other proof of their having ever existed, but that which is yielded to us by their impressions. Not only is it difficult, with many fossil plants, to determine the species and genera in which they should be placed; but frequently it happens, that their appearances differ so much from those plants with which we are acquainted, that it is not possible even to determine their proper station in the natural orders of plants. Among the remains of plants of this latter description may be mentioned those of which we have been just speaking, the appearances of which seem to be such as to defy description. You have already observed the avowed inability of

Dr. Woodward and Mr. Da Costa to form a judgment of their nature, or give a satisfactory account of the appearances which they present: a later writer, Mr. Walch, appears to have experienced no less difficulty. In one specimen of this kind, he remarks, the appearances are such, as would have been produced by the feet of a kid, and even suggests that the impressions on its surface might have been the track of some such animal.

To particularize all the different known plants which have been supposed, by different authors, to have been seen in a fossil state, would employ much more room than can be allotted here for that purpose, especially when we are, at the same time, taught how little reliance can be placed on the opinions thus given. It is, perhaps, sufficient to say, that the fossil plants of Germany have been described by Leibnitz; those of Saxony, by Mihlius; those of France, and particularly those of Saint Chaumont, in the Lionnois, by Jussieu; and those of England, by Dr. Woodward, Mr. Lhwydd, and Dr. Dickinson. Even the Antediluvian Herbarium of the learned and indefatigable Mr. Scheuchzer cannot be relied on: but, on the contrary, by far the greater part of the specimens, mentioned by him, appear to have very doubtful claims to the names which they have obtained. Nor is this to be wondered at, when it is considered, that these were collected from the writings of men, who, although of acknowledged learning, had written when this science was still in a considerable degree of obscurity.

Yours, &c.

LETTER XLVI.

FOSSIL STEMS OF PLANTS....OF THE REED, &C.....FOSSILIUM INCOGNITUM.

THE fossil stems of plants (*Phytolithi Caulis*, Wallerii *&* Linnæi, *Lithocalami*, nonnul.) occur very frequently. They most commonly belong to the family of grasses; and have been sometimes supposed to be analogous with some of the known species of the reed kind. Thus Scheuchzer figures *Arundo Sativa*, Casp. Bauhin. in a schist from the coal mines of England*. Volckman also figures the *Arundo Saccharina*†. The *Acorus* has also been said, by Scheuchzer, to be found in a petrified state; and common Bamboo is mentioned, by Walch, as having also undergone this change. But a review of the fossils of this kind mentioned by Dr. Woodward, and others, will shew that very few indeed of this numerous species can now obtain any other denomination than that of *fossilia incognita;* botanists not having yet been able to discover any existing analogous plants. Pl. III. Fig. 3. represents a fossil of this kind from Chepstow, in Monmouthshire. This, as well as most others of this kind, is little more than an impression, covered with a bituminous film, of a very inconsiderable thickness, its internal part being entirely sand-stone. The explanation of this circumstance does not, however, appear very difficult. The plant, having been surrounded by the soft, or fluid, materials, of which the sand-stone has been since formed, its internal succulent part would soon waste away, and its place be filled with the soft magma; whilst the more solid and ligneous epidermis would remain, and, after a time, would give its correct impression to the surrounding lapidifying matter. Then passing through the bituminous change, it would fill its own mould, with its own altered substance, forming such a surface, as the surrounding stony matter would adhere to but slightly; and would therefore dispose to that separation, by which its form is displayed.

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* Herb. Diluv. Tab. IV. Fig. 1.

† Silesia Subterranea, Tab. XIII. Fig. 7.

This fossil is frequently found, where strata of sand-stone are found nigh to the strata of coal, in various parts of England and of Wales. Mr. Martin says he has seen single joints of this fossil in iron-stone; and one in particular, of a large size, measuring about twelve inches in circumference. Mr. Da Costa relates, that in the collieries at Swanwich, in Derbyshire, in 1752, a plant of the cane kind was found, 14 feet long: it ended in a point at one end, and at the root in a large knot; and in the middle measured nine inches about*. He also mentions, that Dr. Woodward describes two specimens of this kind; one a yard long, and the other six feet and a half in length. Reference to Dr. Woodward's Catalogue shews that Mr. Da Costa was mistaken; the specimens, of which he speaks, had, instead of the smooth, or the striated surface of *gramina*, studs, or tubercules, over the greatest part of its surface†. But Dr. Woodward mentions another specimen, apparently of the reed tribe, which was originally two feet long.

The same circumstance is observable in these fossils, as has been mentioned when speaking of the vegetable remains in the iron nodules. Very frequently, indeed, will the bituminizating process have proceeded to the formation of the black bitumen, or jet, and canel-coal: such has been the case in the specimen already referred to, Plate III. Fig. 3., several particles of black bituminous matter being yet adherent, at the transverse *sulcus* or joint.

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* Philosophical Transactions, Vol. L. Part I. p. 231.

† Catalogue of English Fossils, Part II. p. 104. q. 1.

The specimens of Dr. Woodward, referred by Mr. Da Costa to the reed tribe, are undoubtedly similar fossils to that described Pl. III. Fig. 1., and which is indeed, in many respects, a most surprising and interesting fossil. These fossils differ much in their length, from the size of that which is here depicted, to those mentioned by Dr. Woodward: one of which was five feet, and the other six feet and a half long*. They also differ very much in their thickness, the most common size being less than that of a man's arm; but Mr. Martin observes, that they are sometimes met with of four or five times that size. The substance of these fossils is either a fine grit-stone, with small micaceous particles, or a stone in which no grit appears; but such a mixture of argillaceous and siliceous earth as approaches to a jasper: the colour of both these kind of stones varying, with different shades, from the lightest, to almost the darkest brown. The general figure of this fossil is that of a long, irregular, and compressed cylinder; the surface of which is pretty thickly beset, in quincanx order, with holes, from the bottom of which rise small *papillæ*, like tubercules; but which, being sunk in the hollows, hardly ever rise above the general surface. A substance with a rough imbricated surface, and about one sixteenth of the thickness of the whole fossil, is frequently found passing through it, through the centre of the cylinder; but more to the compressed side; and frequently a sulcus, one edge of which rises into a sharpish ridge, may be observed to run in a line parallel with it.

No conjecture, on which we can venture to rely, has yet been offered with this respect to this fossil. The *Arbor Lavendulæ Foliis*, Dr. Woodward says, hath studs, like these, and set in the same quincunx order. Mr. Whitehurst thinks it most resembles the remains of an *Euphorbia*, of the East Indies†. Indeed, there would be little difficulty in referring it, either to the genus Euphorbia, or to Cactus, were it not for the difficulty of explaining the nature of the internal substance. The surfaces, both of the internal and of the external substance, are frequently covered with a bituminous matter; the interstice being closely filled with stony matter, which would dispose to the suspicion of their having been distinct vegetable bodies, which accident has thus united: but, on the other hand, the frequency with which they are found connected, and the similarity of the mode in which they always appear to have been united, seem to point out that union to be natural, and not accidental. Dr. Woodward described this internal body, in his earlier specimens, as a *medulla* or pith; but afterwards, a more careful view of this body, he says, brought him to think it rather a commencement or beginning of a branch, arising out of the main trunk*. The data which we possess would almost lead to the supposition, that the plant, to which this fossil owes its origin, was of the succulent kind, which contained a more solid part in its succulent substance—but conjecture seems to be hopeless; since the plant appears to have differed so much from any thing which we now know, as to leave us without the opportunity of deriving any aid from analogy, and but little from comparison. The variety in the shape, size, and disposal of the tubercules on the surface of this fossil, appears to be sufficient, to warrant the supposition that the genera and species of this unknown family must have been very numerous. Unable to find sufficient points of correspondence between it and any plant which is now known to exist, we must be satisfied, with Dr. Woodward, whose opportunities for judgment, from the multitude of his specimens, perhaps exceeded those of any one else, to submit to leave it among the *fossilia incognita.*

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* Catalogue of English Fossils, Part I. p. 104. q. 1. and Part II. p. 59. h. 34.

† Inquiry into the Original State and Formation of the Earth, p. 203.

The specimen figured at Pl. IX. Fig. 1., and which was obtained since the foregoing observations were committed to writing, seems to furnish, at least, another conjecture, respecting this extraordinary fossil. In this specimen, of itself highly interesting, is an oblong cylindrical body, which is curiously imbricated on its surface, evidently by the particular arrangement of *squamæ;* from which membraneous productions, exceedingly thin, forming tubuli, pass directly inwards, in a perpendicular direction, to another body placed in the centre of the former. The external surface of this body is also imbricated in a somewhat similar manner, obviously from the regular insertions of the terminations of the membraneous productions, proceeding from the external *squamæ.* A reference to the figure will shew the external and internal imbricated surface, as well as the membraneous productions, forming tubuli, by which both are connected; manifesting this fossil to have been a Strobilus, analogous in its organization, though different in its form, from any at present known.

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* Catalogue of English Fossils, Part II. p. 60.

From the perfect state of seclusion in which this body has been kept, by the close texture of the surrounding argillaceous iron stone; its bituminization has been complete, and every part has been preserved, and is now to be seen in their natural situation. But if, instead of having been thus closely enveloped by argillaceous matter, it had been surrounded by a loose arenaceous mass, and under circumstances less favourable to bituminization, the harder part only of the squamæ, and the central receptaculum, would obtain a prolonged duration of their original form; whilst the connecting membranous substances would waste away, and, as they disappeared, have the space they possessed filled up by earthy particles. Thus at a future distant period there would be produced a stony substance with an imbricated surface, containing within it another substance with a surface imbricated in almost a simlar manner. In a word, a fossil would be formed, which, in its general characters, would resemble the fossil which has so particularly engaged our attention. It must, indeed, be admitted, that th fossil vegetable figured at Pl. IX. Fig. 1., the extended outline to which marks the shape of the complete Strobilus, as acquired by the aid of another specimen, does not accord, in its size, with the fossil with which it has been attempted to demonstrate that it bears some analogy. The difference in size, however, affords no material difficulty; and the difference in the markings on the surface, points out only perhaps a specific difference between these supposed strobuli; but two other circumstances demand still farther examination. One of these is, that the markings, as is frequently the case, and as is the case with the fossil at Pl. III. Fig. 1., is formed of detached spots or impressions, without any line pointing out the figures of the *squamæ*; but this appears to depend on circumstances being favourable, or otherwise, to the forming of the impression; since in a fossil of this kind, nearly half a yard in length, and about two inches and a half in its largest diameter, the lines formed by the edges of the squamæ are distinctly observable: so that nothing remains to contradict its origin having been that which is here supposed, except its extraordinary length and narrowness, when compared with the cones of the genus Pinus. This is the other circumstance to which I alluded; but this form, it is to be remarked, is in perfect agreement with the proportions of the supposed fossil strobilus at Pl. IX. Fig. 1., and is to be considered as strengthening the opinion, that many genera, as well as species, of vegetables, have existed, and been destroyed; and of which we have no other traces than their remains in a fossil state.

The fossil at Pl. X. Fig. 1. also serves, in my opinion, to explain the nature of the fossil depicted at Pl. III. Fig. 6., and already spoken of in a former Letter; since, if the conjectures just offered be right, this fossil, which has so much puzzled oryctologists, may with the greatest reason be supposed to be the Amentum, or Catkin, from which that kind of strobilus, the existence of which has been just inferred, has been formed. The specimen depicted at Pl. IX. Fig. 10. serves also to render more probable, that the flattened specimens already described, and figured at Pl. I. Fig. 6. and 7. and Pl. V. Fig. 8. are the remains of plants of the succulent tribe. Every appearance which this specimen presents, serves to shew that it very nearly resembles the *Cactus Cochenilifer*, one of those plants generally known by the name of Indian figs; and on which that curious insect, the Cochineal (Coccus Cacti) feeds and inhabits.

Yours, &c.

LETTER XLVII.

REMARKS ON LEAVES CONTAINED IN NODULES....IMPRESSIONS OF THE SAME SIDE OF THE LEAF ON EACH NODULE....ACCOUNTED FOR BY JUSSIEU, SCHULTZ, &C....EXPLANATION PROPOSED.

I AM thoroughly aware of the circumstance to which our friend Winton alludes. He desires you to inform me, that he will never believe the impressions on the two halves, of the nodule he has sent me, are the impressions of a real leaf, until I can inform him if, by involving a guinea in plaster of Paris, I could obtain two impressions of the king's head, without any impression of the reverse. The circumstance to which he refers has puzzled some of our most eminent lithologists.

An instance of the erroneous opinions which have prevailed respecting these subjects will be found in the remarks of our counexactly. On the leaves perishing, the crust, thus formed on the surface of the leaf, would sink, and, settling on the soft mud, would give a copy of the impression which the leaf had formed; which would have the exact similar surface, with that which the leaf itself would have presented: the bituminous matter with which the leaf had been charged, from the water in which it had swam; having given to the mould such a surface as would prevent the cast from adhering to it. M. Schultz endeavoured to account for this circumstance in another way. He supposed that the leaf had become involved in a soft earthy matter; and that, as this dried, the leaf perished, and left its mould, bearing the impression of both its upper and under side. At some distant period, he supposes, that some bituminous matter insinuated itself, and filled the cavity which the leaf had left; and that, on dividing the nodule, the bitumen remains adherent to one side; and being separated from the other, it exhibits the form which it has derived from the mould on that side, whilst the mould itself is displayed on the counterpart of the nodule.

You will, doubtless, agree, if the theory proposed respecting the bituminization of vegetable matter accord with the phenomena which are yielded by the vegetable remains thus incarcerated in nodules, that considerable additional confirmation of that theory will be thereby produced; especially if it serves to explain satisfactorily those circumstances which otherwise appear so inexplicable.

The polished surface, and sharpness of impression, observable in schisti bearing the characteristic traces of vegetables, manifest that the substance thus impressed must have been in a very soft or fluid state, when the impressing vegetable substance was applied to it. The disappearance of the impressing vegetable substance implies, that its resolution must have taken place, whilst excluded from the air by the surrounding mass; whilst every appearance seems to point out, that the change, which it has undergone, has been similar to that by which jet and the bitumens, in general, have been formed.

The nature of the change which the leaf, or other vegetable matter undergoes, whilst in this secluded state, is demonstrated still more plainly, on an examination of the impressions of plants on sand-stone; since here the colour of the stone, which is generally of a light yellow or brown, allows the colour which the changed vegetable matter assumes to be distinctly seen. This is the case in Pl. III. Fig. 3, 4, and 5.; and Pl. V. Fig. 4.; in which it may be plainly seen, that the marks proceed, not from impression merely, not in fact from vegetable matter, but from bitumen in a soft state. This is particularly obvious in the specimen represented at Pl. III. Fig. 5.; in which, on examining it by aid of a magnifying glass, the projecting particles of the sand-stone will be seen tinged, as if they had been slightly touched with a brush dipped in light brown bitumen. In the other specimens, just mentioned, the appearances are similar, except as to the difference of colour, which is sometimes so dark as nearly to approach, as in Fig. 3., to black. In the specimen No. 4. the sand-stone is coloured brown beneath the surface, as if by the penetration of the fluid bitumen, which the loose gritty texture of the stone would doubtlessly have readily admitted.

The iron-stone nodule, on being split, affords the most satisfactory evidence as to the nature of the change which the vegetable matter undergoes in these cases, since here, bitumen will uniformly be found to have taken the place, which vegetable matter had originally possessed. Reverting, therefore, only to the position, that vegetable matter, secluded from the air, in a moist situation, will pass through a certain fermentative process, by which it will be converted to bitumen; the key to this enigmatic phenomenon is at once found. The leaf, involved in the tenacious argillaceous matter, necessarily forms a mould bearing its exact form; and after a certain period, during which the surrounding mass acquires a greater degree of hardness, and a nodular form, the vegetable matter changes into bitumen, which fills the mould, and assumes exactly the same form which the leaf originally bore. If, therefore, the nodule be now split, one of these two circumstances will occur—either the bitumen will, by the breaking of the nodule, be separated and lost, leaving the impressions on both sides of the leaf perfect: or it will separate from one side only, and adhere to the other; when the side from which it has separated will yield the impression of the leaf, and the bituminous matter itself, possessing the place of the leaf, will present a surface analogous to that of the leaf from which the impression was originally derived. The separated flake of bitumen, mentioned in the first case, has in some instances been preserved; the description which has been given of it, it being said to resemble a piece of leather or parchment, agreeing much better with its possessing a bituminous nature, than its being a mere dried leaf.

In objection to the proposed explanation of the change, which the vegetable matter undergoes in these nodules, it will occur to many, that the bituminization being performed, under circumstances so favourable to it, there is reason to expect, that the process would pass on to its completion, and that sometimes jet, and the darker bitumens, might be thus formed. It is therefore necessary to state, that this does sometimes happen. Fig. 8. in Pl. I. furnishes an instance of this circumstance. It appears to be the remains of a tuberculated branch of some tree of the pine kind, which has been involved in a nodule of iron-stone, the projecting parts of which are covered with a jet-like bitumen.

The fossil leaf has been said, in many instances, to have been detached from the surface to which it adheres. This is said to have been done by Lhwydd, Buttner, Henkel, Jussieu, and others; but that it was a bituminous, and not a vegetable substance, which was thus found, is evident from their relations. Volckman, who also thus detached them, states, that he found that the earthy particles of the leaves had been deprived of their aqueous and volatile parts; and that, in the place of these, a bituminous matter had insinuated itself*. Walch also remarks, that these leaves should rather be said to be mineralized, than petrified; since the deficiency arising from the escape of the aqueous and volatile parts is, in his opinion, supplied by the addition of bitumen, which he considers as a subject of the mineral kingdom.

In the specimen depicted Pl. IV. Fig. 5. a circumstance is observable, which is, in this place, highly deserving of observation. Lhwydd and others remark, that sometimes, though rarely, the leaf will be found so well preserved, that even the colour may be discerned: and in this specimen the marks of the leaves are evidently of a very dark olive green. But an accurate inspection with a lens demonstrates that the same circumstance has occurred here, which is frequently met with in the bituminization of wood—the bituminous matter retains the colour of the vegetable substance from which it derived its origin—that which appears to be the leaf being evidently a thin shining bituminous film.

Yours, &c.

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* Silesia Subterranea, p. 105.

LETTER XLVIII.

FOSSIL FLOWERS....THEIR EXISTENCE DOUBTFUL....FOSSIL SEEDS AND SEED VESSELS....FOSSIL FRUITS.

When the extreme delicacy of structure is considered, which belongs to the flowers of plants, little expectation can be entertained of often finding these in a petrified state. The tender and almost succulent substance of the petals, stamina, and pistilla, will furnish very little reason for supposing, that they should resist a destructive resolution, sufficiently long to allow them to pass through those chemical changes, by which such a length of duration would be given to their original forms, as would secure their passing unchanged, in their figure, from the vegetable to the mineral kingdom.

This consideration necessarily leads us to doubt, if any reliance can be placed on the accounts which have been given, by different authors, respecting the existence of fossil flowers. Indeed, the earlier writers on this science too frequently admitted resemblances, when the connection between the supposed model and archetype were too equivocal to authorize them. Thus Mylius imagined that he traced the flower of the mouse-ear on a flint, and the rose of Jericho, on a schist from Manebach; both of which Mr. Walch believes were, in reality, merely impressions of trochites. Not having myself seen any fossil which can with certainty be said to have had such an origin; nor having seen any representation, or description, which would fully authorize the admission of their existence; and not conceiving that the supposed fossil flowers of plants, of the verticillated order, would be capable of being distinguished in that state, I have not ventured to introduce the delineation of a fossil flower (*Antholithus*); nor does it seem necessary to dwell longer on the consideration of substances, whose existence is merely conjectural.

In the fifth volume of the Transactions of the American Philosophical Society, is a curious account, in a letter from Colonel Bull, of a vegetable found under ground. I take the pleasure, Col. Bull says, of giving you an account of a singular blossom, which I discovered last May, in digging of a mill-race, on Opeck on Creek, through a rich bottom of low ground, covered, in general, with well-grown large timber of various kinds, particularly oak, poplar, and walnut; several of which trees are from three to four feet through, standing on the ground through which the race was dug. The curiosity is this, that between five and six feet under ground, chiefly a loomy, solid clay, one of the diggers discovered a blossom, not in full bloom, *nearly of the colour of the lilac*, which struck his attention. He called me to see it, not knowing what it could be. Upon viewing it, I recollected the form, and told the diggers it was the same kind of blue flower, which had grown upon the surface of the ground adjacent, and was then faded. In order to prove it, I desired one of the men to dig up the root of the one under ground, and the one upon the surface, which upon examination proved to be of the very same kind. The body of the earth, where the plant was found, must have been formed, perhaps, some centuries, by reason of the uncommon size of the timber which it contained, and from which the most heavy part of the mill timber was procured.

Our inquiries respecting the remains of the seeds and seed-vessels of different vegetables, *Spermolithi*, Linn. of former ages, may be hoped to be rather more successful; since these do sometimes possess such a degree of solidity, that when they are placed in situations which prohibit their vegetation, will allow of their duration, until their bituminous change is effected.

This necessary degree of hardness will chiefly be found in those fruits or seeds, the external parts of which have a tough ligamentous covering, like that of the chesnut; a hard scaly covering as in the cone of the pine-tree, where the pericarp, formed from an amentum, consists of hard scales laying over each other; a tough farinaceous substance which becomes dry and hard, as in the coffee-berry; an osseous or bony covering, as in the hazel-nut; or a still harder investiture, as the stone of pulpy, or fleshy fruits *(drupæ)*.

Bajer describes several stones, bearing a near resemblance to fruits; such as olive, almond, plumb, and cherry stones, apples, pears*, &c. But that these are accidentally figured stones, not deriving their forms from the fruits they resemble, is most probable, from the manner in which they are spoken of, he considering them himself rather as lusus naturæ. Among these, is one said to appear like a pod of capsicum; whilst another is said exactly to resemble a musk-pear, a fragment of a shell completely supplying the place of a stalk.

Scheuchzer describes a petrified nutmeg, as being a white flint of a compressed cylindrical form, marked with striæ passing from one end to the other, and bearing a strong resemblance to the nutmeg†. The figure, however, certainly more resembles that of a coralloid than of a nutmeg. He also figures, in Fig. 89. of the same work, a pyritous fossil fruit of a very curious structure, which is sulcated from the apex to the base, and marked with small projecting points along its lower edge, so as to give it somewhat of the appearance of a coronet.

Helwing mentions a petrified walnut, in such a manner, as to lead to the supposition that its resemblance to the fruit itself must have been very close. The petrifaction of an almond, mentioned by this author, does not seem to have approached the fruit very near in similitude. He also describes a black stone as being very like to a small smooth bean*. But when it is considered, that at this period the notions entertained respecting the petrifaction of vegetable substances were so incorrect, that the petrified spines of the echinus, or sea-urchin, were referred to the vegetable kingdom; and that the accidental forms of pyrites, as well as of argillaceous, and siliceous pebbles, must often approach to the globular, or oval form of fruits, these accounts should be received with some degree of hesitation. With a similar degree of scepticism should several of the petrified fruits be regarded which have been described by Mylius, Volckman, and others: the necessity of which caution must be evident, when it is considered, that Scheuchzer has collected, in his Herbarium Diluvianum, and Appendix, many supposed fossil fruits which certainly have no right to be so considered.

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* Oryctographia Norica, p. 45.

† Lithographia Helvetia, p. 42. Fig. 57.

In the museum of the late John Hunter, Esq. now in the possession of the Royal College of Surgeons, is a substance which has been considered as a fossil walnut; appearing to have been formed from the internal part of the nut only. It bears an exact resemblance, in form and colour, to its supposed prototype, except being of a whiter colour, than the inner part of a walnut would be after a few months keeping. From this circumstance chiefly I am led to suspect this rather to be a specimen of human ingenuity, than of a vegetable substance, changed in its nature, by a natural process.

In the Philosophical Transactions†, several of the fossil fruits are figured and described, which have been discovered in the Isle of Shepey, and which were sent to James Parsons, M.D. by Mr. Jacob, who published, at the end of his *Plantæ Favershamensis*, an account of the fossils he had collected there in the course of thirty years. Among these appear to have been, a small plumb-stone, a cherry-stone, a berry of the Sapindus, or soap-tree of America; the external husk of the fruit of the Sapindus; a young sand-box, or fruit of the Hura; coffee-berries; an acorn, without its cup: besides these he describes others, of the original nature of which he seems to be less confident: among these are two species of beans; a compressed pod, resembling the Arachidna, or under-ground pea; a seed resembling the seed of some large gourd; some exotic fruit, like a small melon; a stone resembling that of an East-India mango; a fruit somewhat resembling that of the Euonymus latifolius of Cluvius; a small bean, resembling a horse-bean; a species of chesnut, like the horse-chesnut of America; a fruit resembling a small Palma Coco; another, seeming to be a species of foreign walnut; and others, which seemed to resemble Myrobolans and Phaseoli.

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* Lithographia Angerburgica, p. 37.

† Philosoph. Transactions, Vol. L. Part I. p. 396.

From the state in which these are found, and from want of their accordance, in every respect, with the seeds or fruits which they are said to resemble, Dr. Parsons, very properly, does not too strenuously insist on their having been those identical seeds, or fruits, to which their appearances approximate. Indeed he candidly acknowledges the difficulty of deciding with respect to them: and particularly mentions two specimens, which he thought were figs, petrified when hard and green; being then, he thought, capable of being impregnated with pyritical particles, which might prevent their perishing. These, however, he afterwards found were fossils rather deserving to be classed with the Fungoides: among which he also places another fossil which he, at first, was inclined to consider as a fossil fruit.

To shew what caution is necessary, in admitting as real petrifactions of fruits, many of those substances which have been so described by the earlier oryctologists, I can assure you that I could have laid before you the figures of apples, pears, plumbs, &c. which would pass with many unquestioned; but which undoubtedly owe their forms to mere accident. In particular, I could call your attention to a siliceous stone, which not only bears the exact form of a pear; but which has a regularly-formed depression, at the smaller end, resembling that which would have been left on the coming out of the stalk; the stone, at this part, on being examined with a glass, appearing evidently tinged with green: but that it has not owed its origin to the fruit which it so much resembles, is, however, obvious, from its having no correspondent depression at the opposite end. I might adduce other bodies, bearing a very similar appearance, at least in their forms, with oranges, apples, figs, &c. which have originally been of marine growth; having been fungi, sponges, and similar productions. Among these may be also placed a siliceous fossil body, resembling, on its external surface, an enormously large nutmeg; but having been cut and polished, several lines are shewn, passing like radii from the centre to the circumference, yielding a very uncommon and beautiful appearance. There appears to be very little doubt of its being the same kind of body as is depicted by Scheuchzer, as a petrified nutmeg*.

As an additional proof of the propriety of receiving the earlier accounts of the petrifaction of the seeds of plants, and particularly of grain, with considerable caution, I must refer you to the fossil represented Pl. III. Fig. 6. A small specimen of this fossil is accurately depicted by Swedenborg, and described as resembling a species of Indian corn; "Speciem præbet spicæ tritici Indici (mais) dicti, nisi forma esset plana†."

Thus Scheuchzer also figures a fossil which he not only describes as an ear of corn, but reasons from its figure and fulness; and thence derives arguments in favour of his opinion that the deluge took place in the month of May‡. But Mr. Walch remarks, with much propriety, that the body figured by Scheuchzer has much more the appearance of a zoophyte, the rays of which are divided by transverse lines, marking their separation into distinct vertebræ.

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* Herbar. Diluv. Tab. XIII. Fig. 2.

† Emanuel Swedenborgii Miscellanea observata circa Res naturales, &c. pag. 15.

‡ Herb. Diluv. Pl. I. Fig. 1. p. 7.

Of the spica secalina & graminis panici, mentioned by Dr. Richardson*, we can form no just opinion, as we receive no aid from either description, or figure; and with respect to the ear of barley, a figure of which was given by Mylius†, which was repeated by Scheuchzer‡, it obviously does not bear the proportions, or the form, of an ear of that kind of grain.

The bodies, whose appearances most warrant the opinion of their having been the ears of corn, are the *Stangengraupen* of the Germans. These are flat, oblong, blackish, and sometimes greenish bodies; but becoming white, and acquiring a metallic lustre, on their prominent parts, by friction. They have been supposed by many to be mineral substances, to which mere accident has given their present forms; but that they are really vegetable substances, which have acquired an impregnation with metallic particles, there cannot exist a doubt. These bodies vary very considerably in their form; but are generally flattened, and are studded with little round prominences, bearing very much the appearance of corn, which has been transmuted into silver. They are but very rarely found, and are said to have been only discovered in the copper mines at Frankenburg, in Hesse. M. Lihman, who has written a tract expressly on these substances, does not consider them as changed vegetable substances; but as being originally of mineral origin. Having subjected them to a chemical analysis, he discovered that they contained a small quantity of silver, with a large portion of copper, combined with arsenic, sulphur, and iron. Wolfart has delineated these substances with great exactness, and describes them as *Spicæ frumenti metallares*, acknowledging himself not to be able to determine the particular species of grain from which they had originated‖. By a reference to Pl. IX. Fig. 6. and 7. you will perceive a representation of two of these bodies, which I have purposely selected as throwing some additional light on this subject. The specimen represented at Fig. 6. bears the appearance very much of having been some species of grain in ear, or perhaps of some small cone or strobilus; but their original mode of existence is best ascertained from the appearance which is yielded by the specimen figured at Fig. 7. where is evidently exhibited the stalk and husks from which the grain or seeds have fallen. The width which this specimen possesses, making every allowance for compression, will undoubtedly strike you as much greater than that of any known vegetable, the grains of which are of no larger size than those which are represented at Fig. 6. These seeds, it may be also remarked, differ essentially in their disposition from that which takes place in the spikes of the grass tribe, having much more the appearance of that of the seeds in the strobili of coniferous plants, which seeds they also appear to resemble in shape. I am, therefore, of opinion, that we must be satisfied with considering these as fossils, whose origin must be referred to some hitherto unknown subject of the vegetable kingdom.

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* Ichnograph. Lithophyl. Brit. p. 108.

† Saxon. Subter. Memorab. p. 15.

‡ Herb. Diluv. Tab. V. Fig. 4.

‖ Histor. Nat. Hass. Infer. p. 35. Tab. V. Fig. 5. and 6.

M. Jussieu discovered on a stone, which he found at St. Chaumont en Lionnois, in the earth, near to the coal, an impression, which, he thought, upon close inspection, and comparison with some seeds he had received from Pondicherry, bore an exact resemblance to the fruit and seed of the Arbor tristis, of travellers, or the *Mania Pumeram* of the Hortus Malabaricus, p. 35. mentioned also by Mr. Ray, in his History of Plants, p. 1698. This tree, it appears, grows only in the Canaries, at Malabar, on the coast of Coromandel, and some other parts of the East Indies*.

It is a circumstance very difficult of explanation, that siliceous petrifactions of the roots of plants, or of trees *(Phitolithi Radicum,*

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* Memoire de l'Academie Royale, 1723, p. 69.

Rhizolithi) occur more unfrequently than those of any other parts of vegetables which possess a woody hardness. Petrified roots are indeed mentioned by some authors; but are spoken of under circumstances which imply their rarity. Thus Scheuchzer has *No.* 80. *Arundinis vallatoriæ radix*[*]. Luid. p. 180.; but a reference to the work of Lhwydd is fruitless, since its number of pages is less than the number referred to; nor do I discover the description of such a specimen. Langius presents us with a figure of a Rhizolithus, of which he thus speaks: "*sublutei est coloris, & radicem pastinacæ tenuifoliæ sativæ radice lutea. Casp. Bauhin. Pin. præsefert, allatus est è Toggio*[†]." But that the substance he thus describes was merely a figured stone, which had by some accidental occurrence assumed the form of a piece of carrot, is most probable: for no fact in the history of these substances is more true than the position laid down by Wallerius, when speaking of the requisites to be possessed by substances to render them capable of becoming the subjects of petrifaction. "Ea," he says, "sit indole & duritia ut non facile putrefactionem, vel aliam destructionem, subire possit, sed diutius in locis subterraneis incorruptibile conservari." Linnæus also says[‡], "Corpora petrificanda sint solida: testæ, ossa, ligna. Succulenta deliquescunt & corrumpuntur antequam indurescant lapidosa." But even a modern author, justly celebrated for his knowledge in chemistry and natural philosophy, speaks of a petrified potatoe, a rhizolithus as inadmissible as that of Lang. Argenville, Hellwing, and others, have also described Rhizolithi; and the last-mentioned author, not only speaks of them, in even an agatine state, but distinguishes them into the roots of different trees. It must, however, be obvious, that the difference between the roots of different trees can hardly ever be such as to allow of its being ascertained, to what kind of tree a petrified fragment may have originally belonged. Thus the specimen represented at Pl. II. Fig. 2. indubitably deserves to be considered as a true Rhizolithus; since although it now possesses the hardness, and bears the polish of agate, its external form, as well as its structure, sufficiently testifies it to have been originally the root of a tree; but of what tree, certainly, no judgment can be formed. From the manner in which these bodies are spoken of, by the older writers on these subjects, it appears to be evident, that they have frequently referred to this head merely some of those tufaceous incrustations, which form round pieces of twigs and branches of wood; and which, from their sometimes also resembling the fragment of a bone, were generally known by the name of *Osteocollæ*. Gesner, in his excellent Dissertation on Petrifactions, is obviously of this opinion: he says, speaking of Rhizolithi, "Huc pertinent petrificata ramosa calcaria, arenacea, argillacea corruptarum in terra radicum sedem occupantia, Osteocollæ & Stelechitæ dicta*." Indeed, so much confusion has existed with respect to this substance, that many have confounded it with the stalactite, although the great and venerable Aldrovandus had, at that early period, fully marked the difference. The term *Rhizolithus* has also been applied, by some, to substances which have obtained their form, from the remaining earthy particles of roots, and which, being blended with other earth, in the mould of the decayed root, have preserved somewhat of their original form; but, the vegetable structure being entirely destroyed, they can only deserve to be considered as the *vegetabilia terrificata* of Wallerius.

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[*] Appendix Herbarii Diluviani, p. 70. [†] Historia Lapidum Figurat. Helvetiæ, p. 54.

[‡] Systema Naturæ, tom. iii. p. 154.

I have hitherto supposed that bituminization was a process, to which all vegetable matter was subjected, under certain circumstances; and that by this operation it became liable to the influence of another process, that of petrifaction. But the absence, in general, of roots, from the collections of petrifactions, points out such a deviation from this assumed law of nature as seems particularly to demand investigation; by which we may, perhaps, be enabled to determine, whether this supposed law has been admitted upon false grounds; or whether it results from that arrangement in the ever admirable œconomy of nature, by which her multifarious operations are carried on, without any injurious interference with each other. That the latter is the case will, I trust, appear, from a slight attention to the following observations.

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* Joannis Gesneri Tractatus Physicus de Petrificatis, p. 21.

No circumstance has ever been remarked which will authorize the supposition, that vegetable matter can be liable to the bituminous change, until deprived of all the energies of vegetable life. But roots, as is well known, long retain their vegetative powers after entire separation from their trunk. The trunk, indeed, soon ceases to live; but the root will be found, after a long period, to be alive: feeding on its own juices, and at last terminating this mode of existence, by changing into a soft pithy substance, which soon resolves into vegetable earth (*Vegetabilia terrificata*, Waller). Hence it appears, that, after separation from the bodies which they supported, the roots of trees continue to possess those powers, which most strongly oppose the bituminous change; and when deprived of these powers, they have suffered such an exhaustion of their principles, that their resolution into almost mere earth speedily follows.

It is observed by Liebknecht, when speaking of the ferruginous tree found in Laubac, that, although the greatest care and industry was employed, only very few pieces were found which had the appearance of roots; and even these, he acknowledges, bore very few, if any, decided marks of having originally existed in that state*.

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* Discursus de Diluvio maximo, &c. a Jo. Georgio Liebknecht, cap. iii. sect. 22. p. 285.

been the stone of some drupaceous fruit, and which was so completely pyritous, that, on being cut, the polished section, represented Fig. 7., shone with the most brilliant golden lustre; the traces of its texture not being discoverable without the aid of a lens of considerable power. Of the remaining specimens, I regret that, although favoured by the assistance of the distinguished botanist already mentioned, and by several other gentlemen eminent for their knowledge of the vegetable system, I am unable to supply you with much information respecting the plants to which they have belonged. Fig. 2. appears to have been the seed of some plant of the leguminous kind; the skin of which is in part removed, shewing the fine pyritous clay with which it has been filled. Fig. 3. appears to have been a seed of the same kind; the skin remaining whole, but having wrinkled up to adapt itself to the inclosed matter. Fig. 4. and 9. resemble the seeds of a phœnix; or rather of two different species of that genus. Fig. 9. is very like to the stone of a common date. Fig. 10. and 12., but particularly the latter, approach very much in appearance to the common pea. Fig. 13. 14. and 18. are quite different from any thing at present known: a portion of stalk seems to remain attached to each of them. Fig. 6. 21. and 25. appear to have been fruits covered with a coriaceous covering, similar to the chesnut. Fig. 24. and 26. are fruits which seem to have possessed a similar substance, with that of the nutmeg; but differing very much from that fruit, in their external appearance. Fig. 20. and 22. represent the front and back view of a substance which bears no resemblance to the parts of any known vegetable, at least in a natural state. Dr. Smith is, however, of opinion, that its appearance is very much like that of the cup of an oak, in an enlarged state, from the attacks of insects: he having gathered just such at Rome, in the spring of the year.

The nut which is represented at Pl. VII. Fig. 1, 2. is also from the Island of Shepey. The exact appearance of the kernel is preserved in the cast formed within the shell, which is depicted at Fig. 3. It is totally unlike to any thing at present known; but perhaps may be referred to the genus Cocos. This fossil was originally in the possession of Sir Joseph Banks, by whom it was presented to the British Museum.

Fig. 4. and 5. represent part of a nut, which somewhat resembles the former; although the kernels vary considerably in their shape. This fossil was added to the collection in the British Museum, by Mr. Douglas, by whom it is figured and described in his ingenious Essay on the Antiquity of the Earth.

Fig. 6, 7, 8. of the same Plate represents a fossil found in Leicestershire. It is of a triangular form; three raised lines, passing through its length, at equal distances, on the general rounded surface, give it an appearance rather difficult to imitate. Similar fossils are found in Derbyshire, and have been figured and described by Mr. Martin, in his history of the fossils of that county. Like the fossils already described, these must also be placed among those productions of a former world, which are unknown to us; and which lead to the supposition, that a considerable difference must have existed between the subjects of the vegetable kingdom of that period and the present. The fossil depicted at Pl. IX. Fig. 2. is of a very dark iron-stone, of a scoriaceous appearance; bearing very nearly the form of a lemon: but which, however, I rather conjecture to have been the stone of some very large drupaceous fruit.

Although, from the ambiguous nature of the subjects which have engaged our attention, we have frequently been obliged to rest satisfied with conjectural remarks; as yet we have been able, without difficulty, to draw a line of distinction between the subjects of the animal and of the vegetable kingdom. We now come to the consideration of certain bodies of antediluvian origin, so equivocal in their appearance as to render it exceedingly doubtful in which of the two grand divisions of organised matter they should be placed.

So totally different are these bodies from any which are known to exist in the present world, that the mind not only hesitates at determining whether they be of animal, or vegetable nature; but, misled by the various fantastic forms which they assume, is disposed to consider these several species, of perhaps the same genus, as bodies differing so widely from each other as sponges, figs, funguses, nutmegs, and corals. It was by a substance of this kind that, as we have already seen, Dr. Parsons's judgment was so perplexed; he at first considering that to be a petrified fig, which he afterwards concluded to be a substance of the fungus kind. The representation at Pl. IX. Fig. 3, 4. is of a small specimen, being one of those species of this kind of substance, which bears a resemblance to a small compressed fig. The upper part, Fig. 3., has a gentle rising, as if the stalk had been attached at that part; and on the under surface, Fig. 4., is a similar depression with that which is borne by the corresponding part of a fig. Having been able to mark these substances under many of the various shapes they assume, I have no doubt of their being of marine origin, and the residence, and perhaps the workmanship, of animals; they would not, therefore, have been mentioned in this part of our inquiry, but for the sake of shewing you that we have now arrived at the examination of substances which, though apparently of a vegetable, are really of an animal nature; and that we have therefore reached the line at which our present labours should cease.

Having now furnished you with what information is in my power respecting real petrifactions of vegetable substances; it becomes necessary to say a few words respecting those stones which, from their accidentally possessing the forms of certain parts of vegetables, have been by many supposed to have actually derived their figures from the substances which they so much resemble. These stones, the *Phytoglyphi* of Wallerius, being a species of the *Petrificata ficta* of Linnæus, *Lithoglyphi* of Wallerius, and *Lapides figurati* of others, have, from their great similitude to different parts of vegetables, occasioned numerous mistakes in the writings, especially, of the earlier oryctologists. From circumstances which affect the formation of stones, they are more likely to be disposed to assume the oval or globular forms of seeds and fruits than of any other parts of vegetables. To such, therefore, our present consideration will be chiefly directed.

Among those figured stones which have obtained the greatest celebrity, from their resemblance to fruits, are the melons of Mount Carmel. *Melopeponites*, Aldrovandi. These are crystalline geodes, which not unfrequently bear the forms of melons and other fruits: the rounded, granular-formed crystals having been supposed to resemble the seed, and credulity having sometimes gone so far as to fancy, that the smell of the fruit was yet discoverable in its supposed petrified remains. One of these petrified melons of Mount Carmel, of a small size, and opened, is represented in Plate IX. Fig. 5. The bare-footed friars of Mount Carmel have chiefly contributed to the fame which these substances have acquired, they having, by the aid of an old legendary tale, been able to render them an article of profit to themselves, and of great curiosity with travellers, who have resorted to Palestine. On this mount there is a particular spot, which is termed the *field of melons*, where these bodies used frequently to be found; but which of late appears to have been exhausted, by the traffic of preceding years. The legend says, "On this spot was a garden-ground, well stocked with melons; and that the prophet Elias, the founder of the monastery, once asking the gardener for one of his melons, he, with churlish humour, answered, that they were not melons, but stones; on which they were immediately changed to stones, and have so remained to the present day." But, according to the industrious friars of the order of Elias, the punishment of the gardener's pertness did not rest here; since they furnish travellers with other fruits, which, happening to be in the same garden, shared the same fate: thus we have the *Pomum crystallinum*, &c. For the mode in which this extraordinary miracle was performed I must refer you to a former Letter*, not thinking it necessary to pause any longer here, in removing any doubts which scepticism may have suggested.

Similar tales have been invented, for the purpose of accounting for other stones which have borne the similitude of vetches, of peas, &c. Thus the Virgin is said, in passing from Bethlehem to Jerusalem, to have beheld some peasants who were sowing peas, and begged they would present her with some, which they refused, saying they were merely stones:—Then such, she replied, shall you reap; and since then, it is said, nothing will grow there except these stones, which possess the form of peas. For the better understanding of this miraculous transmutation I must again refer you to a former Letter†; and when I inform you that these petrified peas are formed of a calcareous stone, of a yellowish white hue, and frequently irregular in their forms, you will with very little hesitation believe that their origin is similar to that of the Confetto di Tivoli which are there described. I need hardly remind you that immense quantities of stone exist in different parts, formed of similar round bodies, which are termed *Pisalithi*, originating in stalactitic concretion. When these concretions assume a smaller form, they have been termed *Meconites*, or *Cenchrites*, according as they most resemble the seeds of the poppy or of the millet. When the mass has resembled a collection of the grains of wheat,

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* Letter XXXII.

† Letter XXXIX.

&c. it has been termed *Lapis frumentarius*, and it has been considered as the petrifaction of such grain.

But one of the most curious of the suppositious petrifactions of vegetable matter is petrified bread *(lapides paniformes—panes petrifacti, seu dæmonis. Teufel Brod.)*. Bruckman gives a very particular account of different petrifactions which had been supposed to have been of this kind.

In the church of St. Peter, of Leyden, a stone is preserved, the history of which is, that—in the year 1316, a poor woman, deserted by fortune, and almost perishing, with her numerous children, for want, humbly petitioned her rich sister for bread. She, however, refused to supply her, and swore, in the most solemn manner, that she had no bread in the house; which the other doubting, she added, if there were, might God turn it into stone! and directly, to her astonishment and horror, the bread became stone. An author, of the name of Hartnoch, also relates as wonderful a story. A poor woman, oppressed by misery and want, was passing along, with one child in her arms, and another following at her heels, all nearly perishing with hunger, it being in the time of famine. They met a brother of the holy order of St. James. She implored him, for the mercy of God, to spare her a morsel of bread for herself and almost famished children: the hard-hearted wretch most solemnly assured her that he had no bread; but the woman directly replied, that she saw he had a loaf in his bosom. This the holy brother denied, saying that it was a stone which he thus carried, to defend himself from the dogs. Soon after this he put the loaf to his mouth, with intention to eat of it, when he found that it was no longer a loaf, but a complete stone. Struck with horror, he repaired to the monastery, confessed every particular of his crime, and the wonderful judgment: in commemoration of which, our author says, the petrified loaf was hung up in the chapel of the monastery. We also learn, that at Schemnitz, in Hungary, a woman, despising the sacred institutions, was making bread on the feast of St. Anne, when she found that all her loaves were become stones, whilst in the oven. The learned Bruckman mentions other instances of these miraculous conversions, and particularizes several places where specimens of stones bearing the appearance of petrified bread may be seen; concluding with the following appropriate ejaculation,

> Da nobis panem, Domine! in diebus nostris; non durum & lapideum, sed frugalem ac sufficientem.

I should not have thus introduced, in our examination of the petrification of vegetable matter, the mention of petrified loaves, but for the sake of observing, that, of all the sports of nature, in the formation of stones, these are among the most delusive, and unaccountable; judging from a specimen in my possession, which I understand was purchased by the late Mr. Strange, from Germany, at a considerable expence. Its form is that of a long square, being similar to what are generally called Dutch loaves. Its upper surface is rounded, and of a dark brown, exactly agreeing in shape and colour to the upper crust of such a loaf; whilst its opposite surface is flattened, and of a paler brown; bearing as perfect an agreement with the under crust: both the one and the other possessing the smooth surface of the crust of a loaf. The intermediate substance, answerable to the crumb, possesses, in an extraordinary manner, the rough spongy appearance of the crumb of bread, being even separated by such clefts as might be supposed to have taken place in bread which had been dried by long keeping. The substance of the stone appears to the naked eye like a coarse jasper; but on a close examination, with the aid of a glass, the internal substance is discovered to be formed of very small white siliceous stones, agglutinated by a siliceous medium; and the external part of brown siliceous stones, connected in a similar manner: the substance of our seeming petrified loaf turning out to be actually a plum-pudding stone; formed in some cavity, most probably left by either as timber, or as soil fitted to aid the growth of other vegetables, should undergo certain other changes, by which they will be rendered peculiarly fitted for supporting combustion, in the various modes necessary for promoting the comforts of mankind, and conducting the numerous arts of civilized life.

In this new mode of existence we saw reason for supposing that the combination which took place was such as to resist the decomposing powers of almost every agent, except that of fire: manifesting the completion of the process, and evincing proofs of the most wise and providential arrangement. For thus we perceive that a state of permanency is yielded to the substance thus formed; which substance appears to be intended for the use of man for a period of time, not only beyond our knowledge, but even beyond the reach of conjecture. On the degree of perfection to which this process attained, and on the introduction of various earthy, and other matters, appeared to depend the formation of the different kinds of bituminous substances, and particularly the different varieties of coal.

There also appeared great reason for supposing that, in some situations, and under certain circumstances, this process was arrested, in small detached masses, by their being subjected to particular saline, earthy, or metallic impregnations. In which cases it was presumed, that substances were formed, which, although not so useful to man as those already mentioned, were well calculated to increase his number of elegant luxuries, and to excite in his mind the highest degree of admiration, by their extraordinary, and often exquisitely beautiful appearances. Thus seemed to have been formed the fossil woods; some, at least, of the jaspers; the pitchstones; the wax, or semi-opals; and even the noble opal itself.

It was even conjectured, that on the mixture of bitumen with silex might have depended the different varieties of horn-stone, flint, &c. In confirmation of which, subsequent observation has

The most direct inferences, from obvious facts, remarked, whilst considering the nature of those bodies, which have been the subjects of our correspondence, lead to the conclusion, that, independent of the accomplishment of any other important purpose, by the resolution of a former world, one grand object appears to have been attained—such an arrangement and modification of the seeming ruin, as produced the regeneration of a world, stored, in its deepest recesses, with substances calculated to promote the comfort of man; to tempt him to the exercise of his innate powers; to furnish him with the means of supporting his dominion over the animals around him; and even to urge him to a change from the savage to a civilized state. Another world rises from the overwhelming flood, composed of the fragments of the former, which appear to be blended together, in an apparently disordered and incongruous mass. But, after the lapse of a small period of time, the constituent parts of the newly-formed world are discovered to be arranged, according to those wise laws which the great Creator had decreed from the beginning. The surface again teems with beings possessed of the energies of animal and vegetable life; and after ages discover, that the atoms of which the new world is formed, acting reciprocally on each other, with varying, but appropriate influence, regulated by the laws of attraction, and chemical affinity, compose a variety of new combinations; and the newly-formed world, enriched by the amelioration of its materials, obtains an increase both in its stock of utility and beauty.

This circumstance, which I consider as plainly pointing out the wisdom and power of the Creator, may, however, I am perfectly aware, afford occasion for hesitation to the sceptic, who may imagine that the necessity of forming the world anew implies that its first formation was deficient in design. But considering this planet itself, as probably destined, with the other works of creation, to undergo certain regular changes in its constitution, during the progress of its existence, such changes cannot furnish sufficient grounds, for doubting of the wisdom, or power of God: not even were it discoverable, that this world had undergone several revolutions and reformations; and that, in common language, several worlds had existed before the present. Man, unable to view the connection between these changes, and to judge of the important ends, intended to be thus accomplished, would shew as much folly and presumption, by inferring a narrow limitation of the power of the Creator, on discovering that the remains of former worlds entered into the composition of this, as if he were to make a similar inference, on remarking one of the metamorphoses of the silk-worm, without being acquainted with the other particular circumstances in the natural history of that insect.

Regarding the destruction and renovation of the world in this point of view, the most interesting conjectures force themselves on the mind. If it be apparent that, from the breaking up of a preceding world, the present has derived a higher degree of utility and beauty; may not this also be preparing to undergo, at some distant æra, a new recomposition, by which it may be made to exceed this, in a similar proportion, in the possession of every excellence? May it not thus become fitted for the reception of beings of higher susceptibilities and powers?—But, checking this propensity to indulge in vain, and perhaps dangerous conjecture, we will return to inquiries rather more within the reach of reason; premising only one observation, intended to render more striking the necessity of diffident caution, whilst employing our limited powers of judgment, on any point which involves the knotty question of the origin of evil. How derogatory from the dignity and omnipotence of the Creator, might a presumptuous and short-sighted caviller say, is the unfinished condition of great part of the creation?—not a plant, nor an animal, is there scarcely which exists, but, in its natural state, is so far from perfection, as to require the greatest care and culture, to procure the full display of its beauties, and the developement of its various faculties and powers. But, one more glance is sufficient to discover, that this apparent deficiency of power and judgment is a remarkable instance of the wisest adaptation of means to the producing of a most important end. For when it is considered that the dominion of the earth is given to a being, endued with peculiar faculties, the preservation and improvement of which depend on their due exercise; it surely is not discordant with the correctest ideas of an arrangement, proceeding from consummate wisdom, and accomplished by unlimited power, thus to furnish him with materials on which his abilities may be employed.

On examining those vegetable remains which still displayed some traces of their original forms, appearances were discovered, which seemed to point out a great dissimilarity between some of the vegetables of the former, and of the present world. So great did this dissimilarity appear, as to warrant the conclusion, that either many genera and species of vegetables, which existed before the flood, are now entirely lost, or remain secreted from us in some remote, and hitherto unexplored part of the world. Reasoning by analogy, from the undoubted loss of several species, and even genera of animals, we are led to consider the loss of a part of the vegetable creation as far from improbable. This is a point which cannot, however, be said to be determined, whilst any part of the world, in which they may be concealed, has escaped the examination of the botanist: especially as some very good and learned men have regarded the loss of a single link, in the chain of creation, as inadmissible: it implying, they say, such a deviation from the first plan of creation, as might be attributed to a failure in the original design. But such an inference does by no means follow; since that plan, which prevents the failure of a genus, or species, from disturbing the general arrangement, and œconomy of the system, must manifest as great a

Why the earth was at first so constituted that the deluge should be rendered necessary—why the earth could not have been at first stored, with all those substances, and endued with all those properties, which seem to have proceeded from the deluge—why so many beings were created, as it appears, for the purpose of being destroyed—are questions which I presume not to answer; trusting, however, that what has already been said must render their solution less difficult, and lead to conclusions less repugnant to reason, than some which have been advanced, by men of considerable abilities and learning, I shall here close our correspondence, for the present, experiencing no small degree of satisfaction at finding every fact I have noticed, and every conclusion which they have led me to make, to be in perfect accordance with the highest sentiments which can be formed respecting those laws, by which the regulation of the œconomy of creation was decreed.

Yours, &c.

END OF THE FIRST VOLUME.

[illegible] Plate Bituminous [illegible] wood

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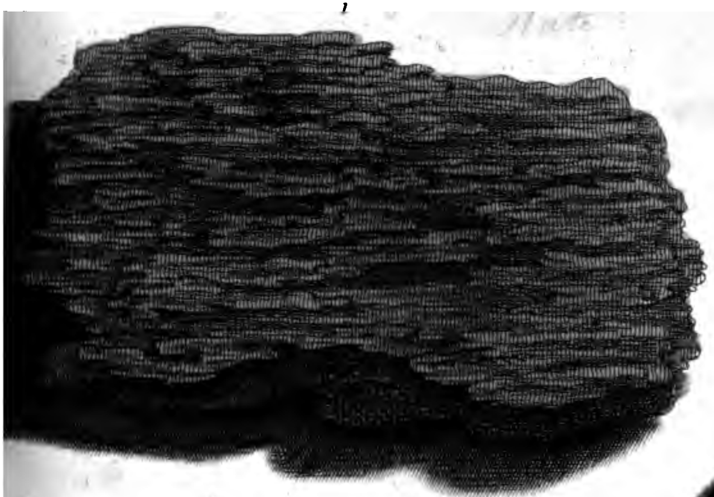

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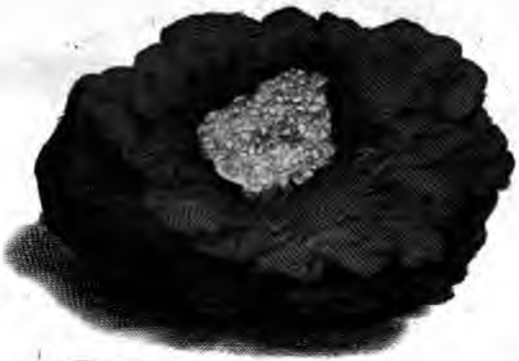

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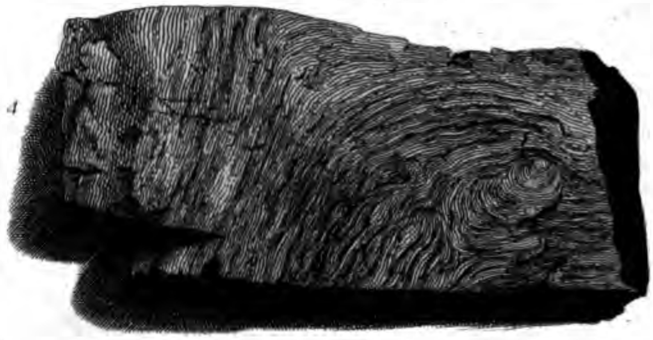

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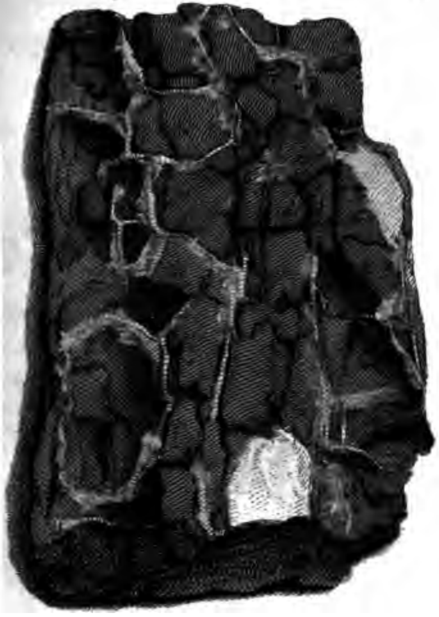

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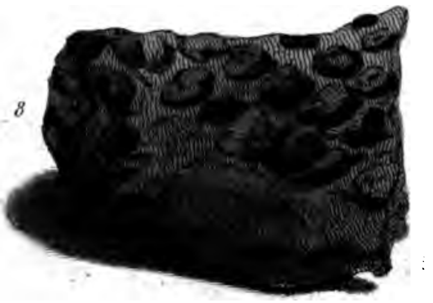

Publish'd by J. Parkinson, Hoxton, June 1, 1801.

J. Springsguth Del et Sculp

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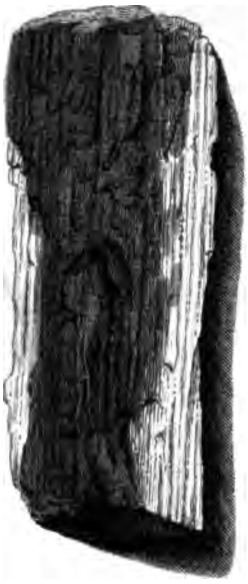

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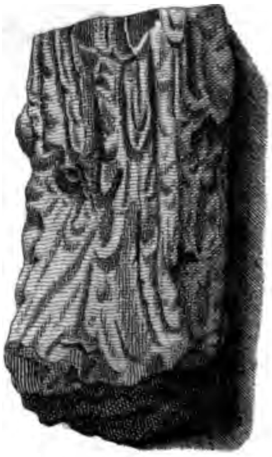

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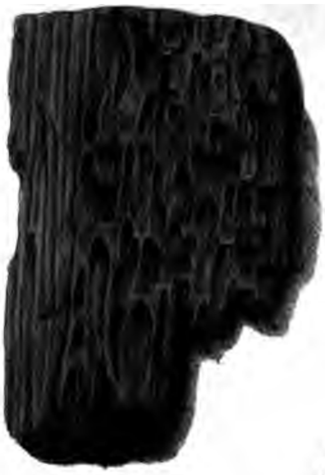

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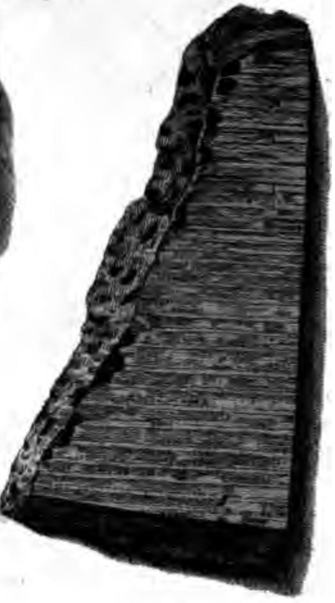

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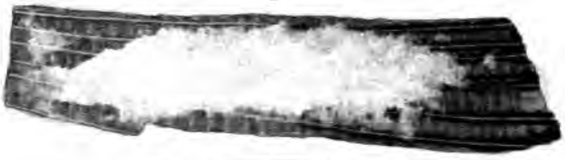

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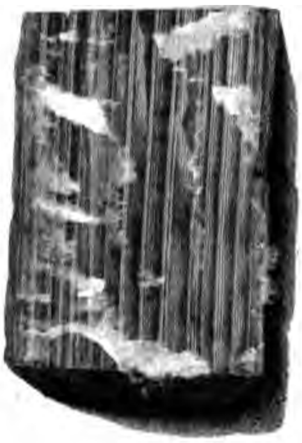

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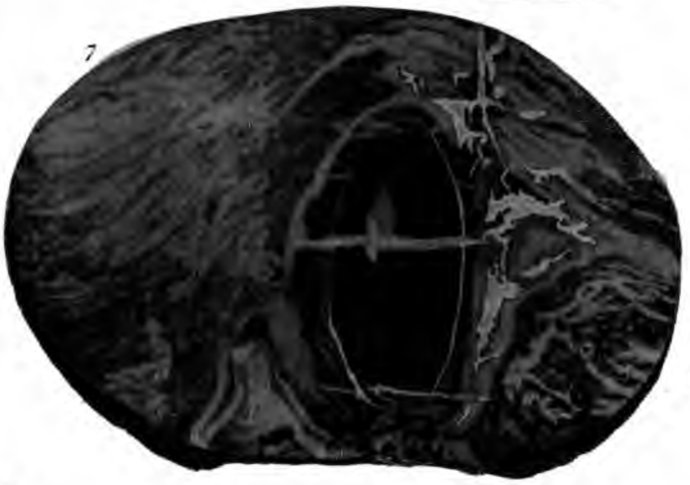

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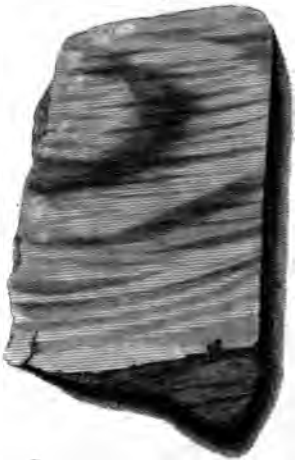

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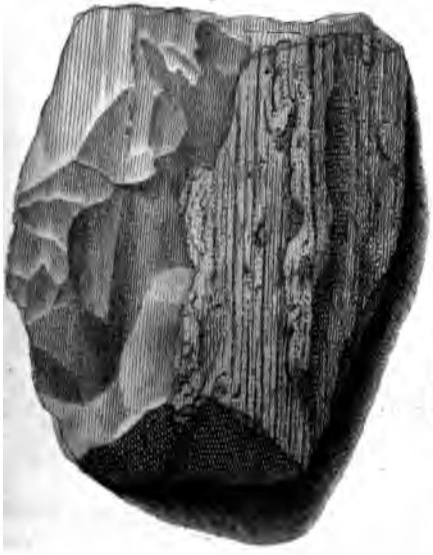

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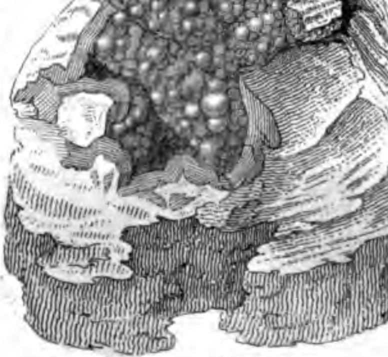

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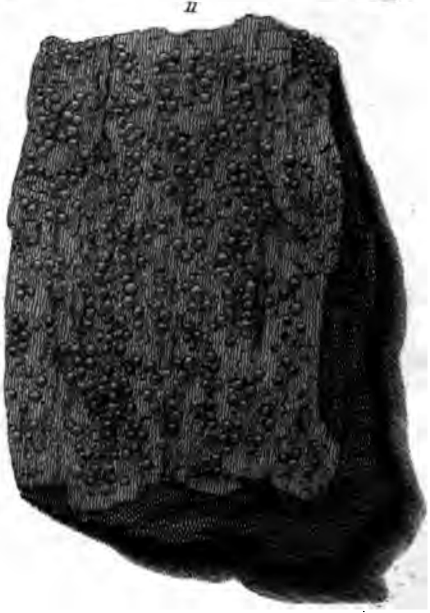
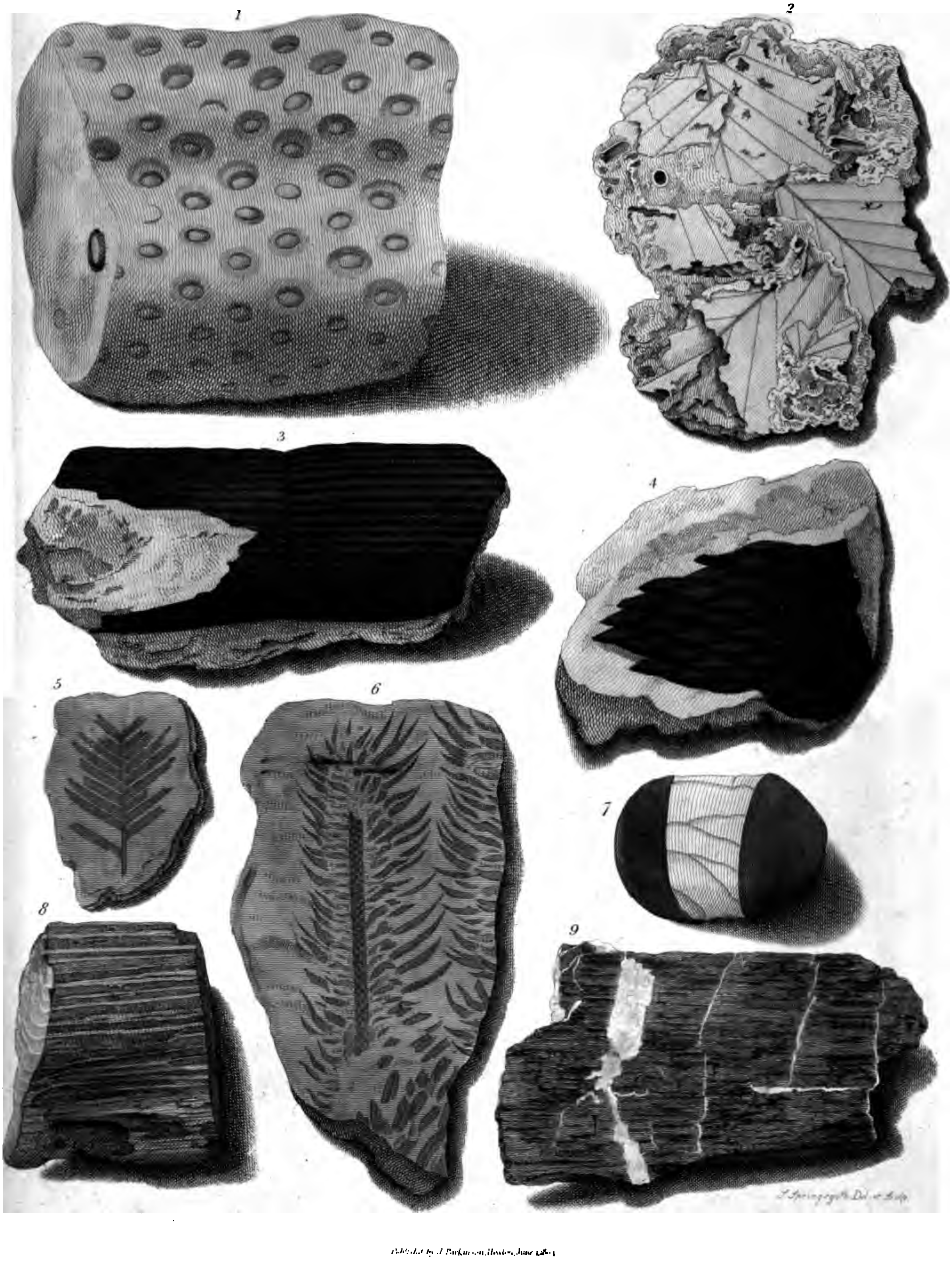


J. Springsguth Del et Sculp.

Publish'd by J. Parkinson Hoxton June 1.1801.

PL. III.



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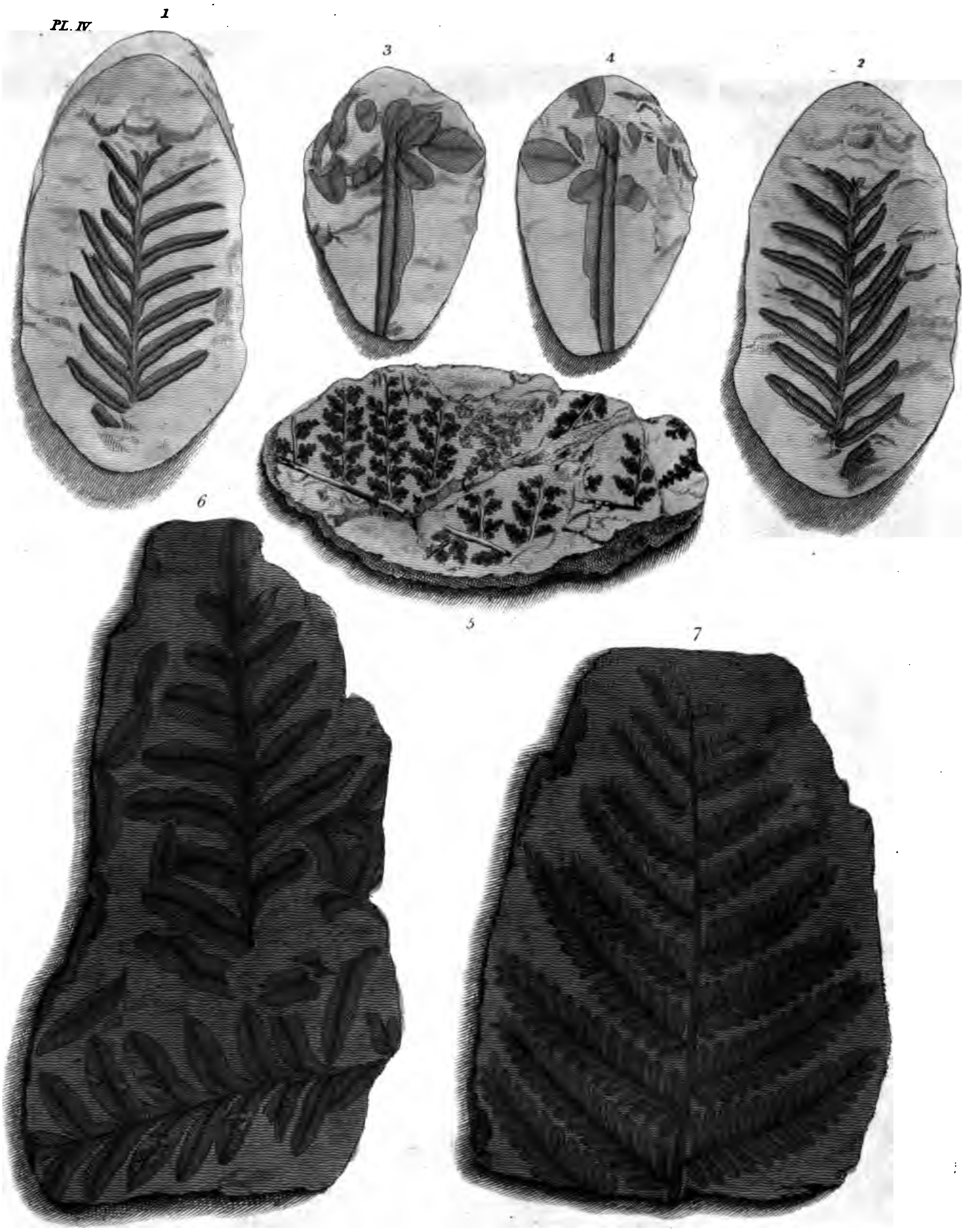
Published by J. Parkinson, Hoxton, June 1804.

PL. IV.



Published by J. Parkinson Hoxton June 1. 1804

PL. V.

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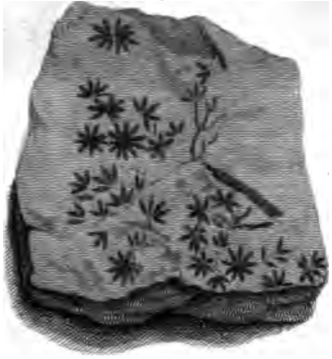

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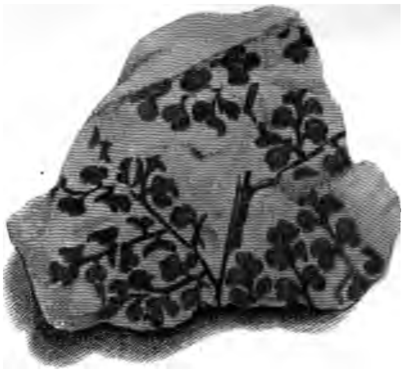

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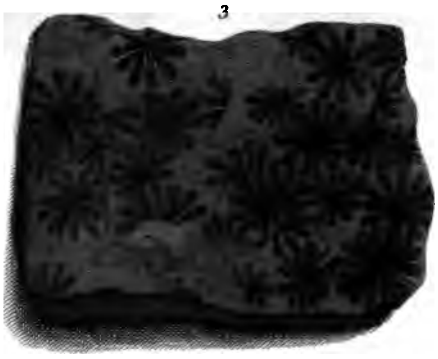

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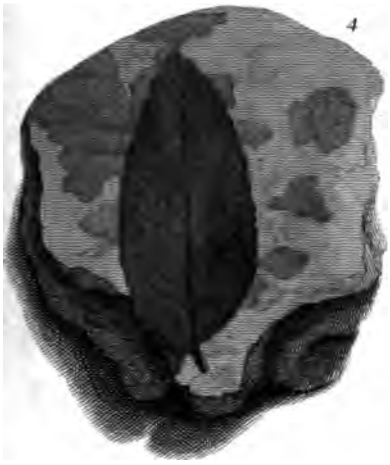

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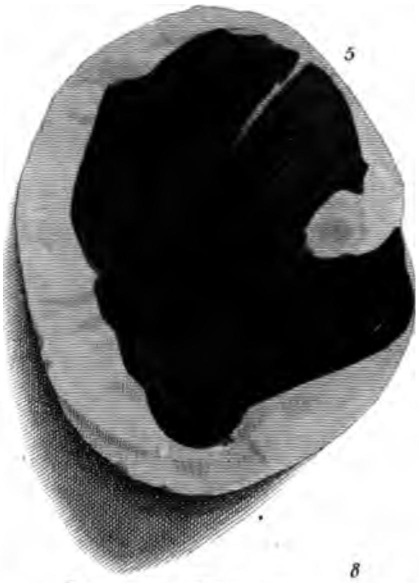

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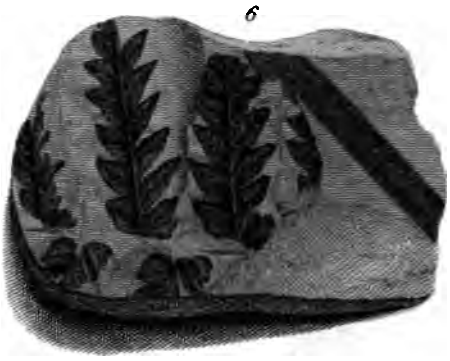

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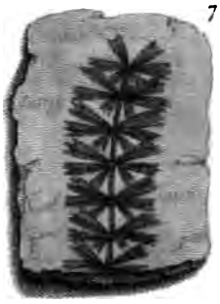

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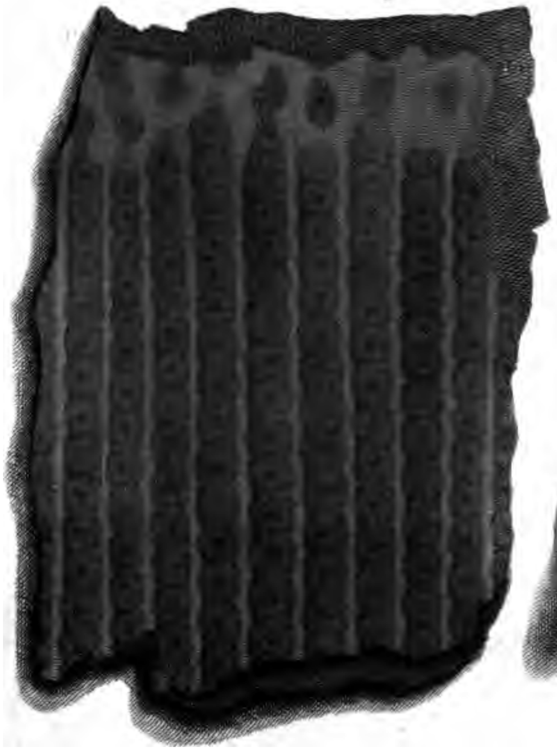

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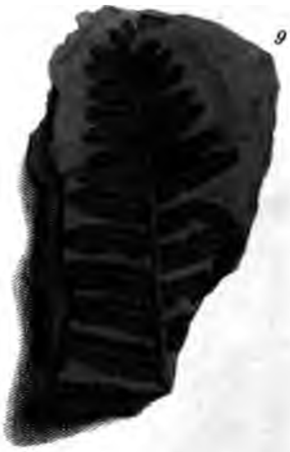

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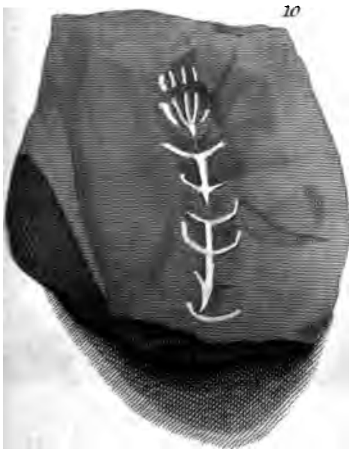

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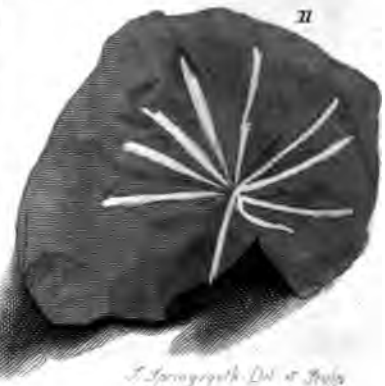
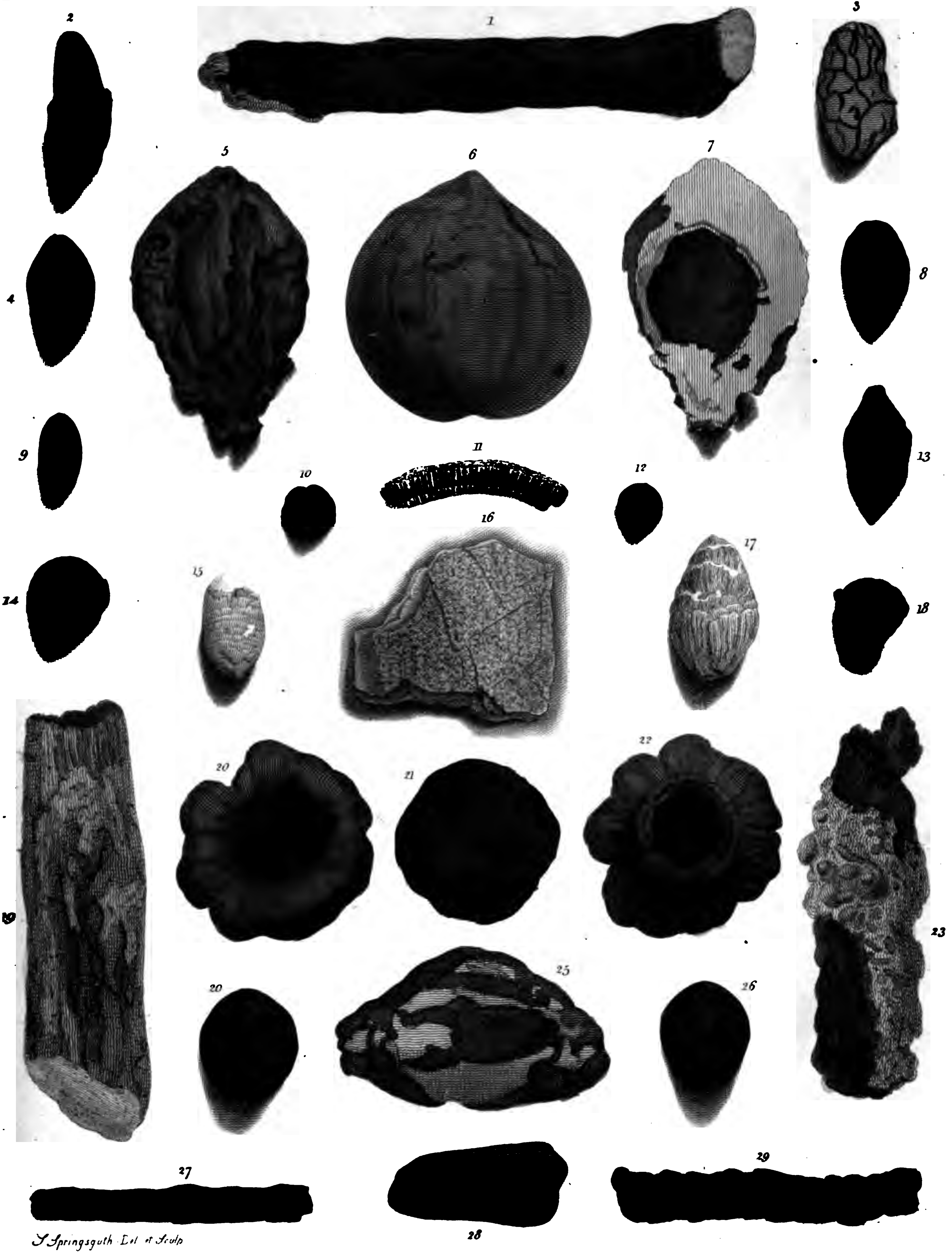


J. Springsguth Del. et Sculp.

Published by J. Parkinson Hoxton June 1 1803

Pl. VI.



J. Springsguth Del et Sculp

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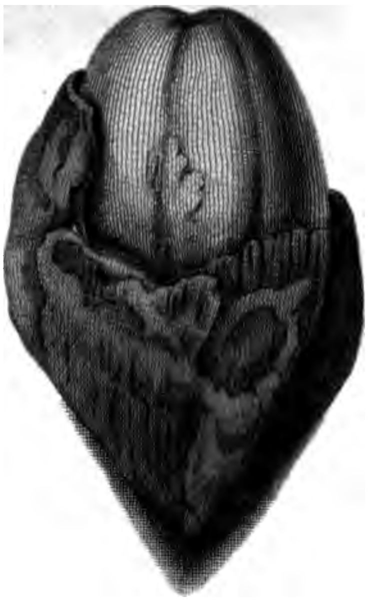
Pl. VII.

1



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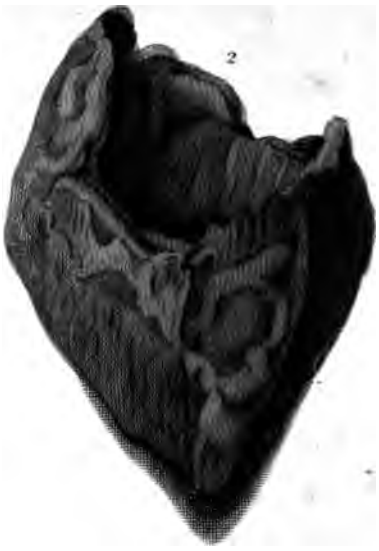

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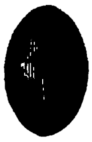

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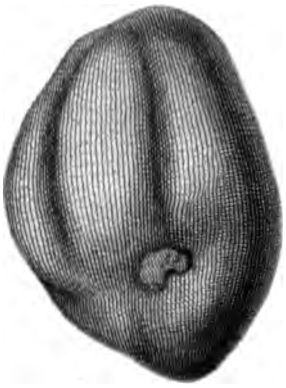

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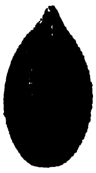

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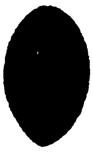

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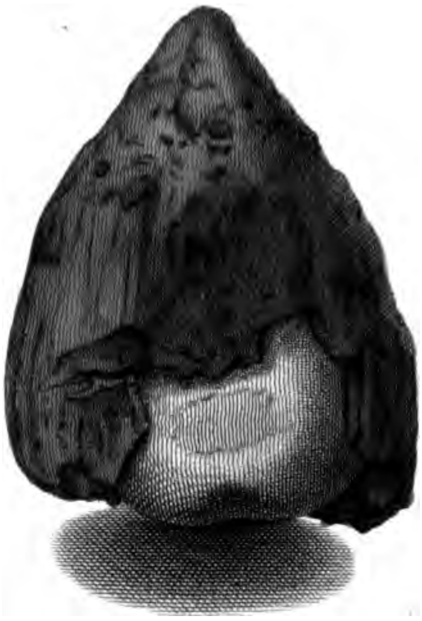

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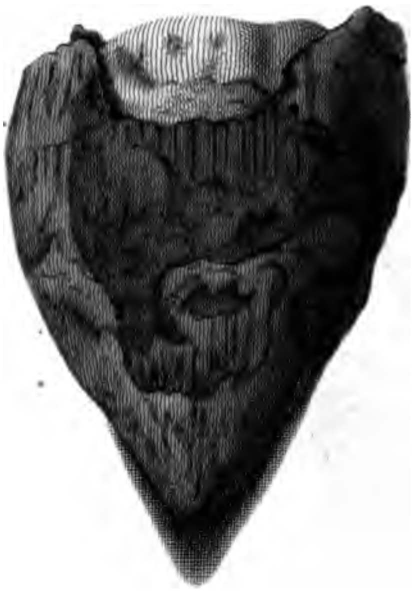

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PL. VIII

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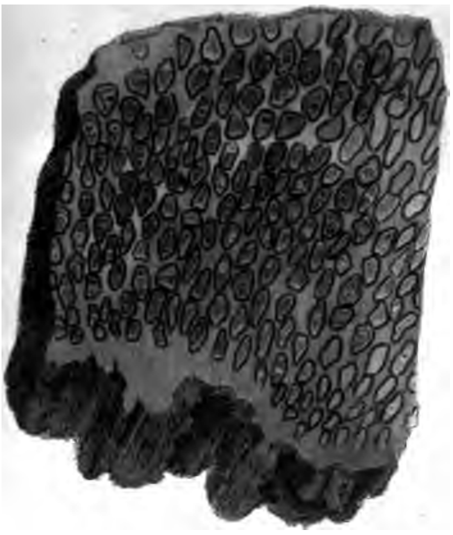

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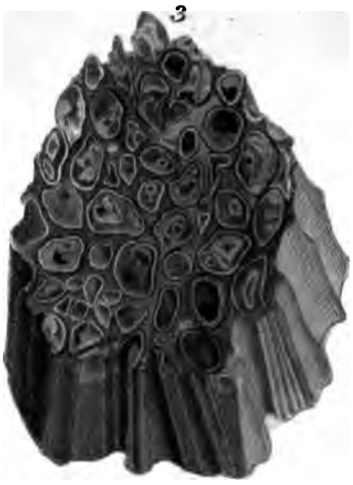

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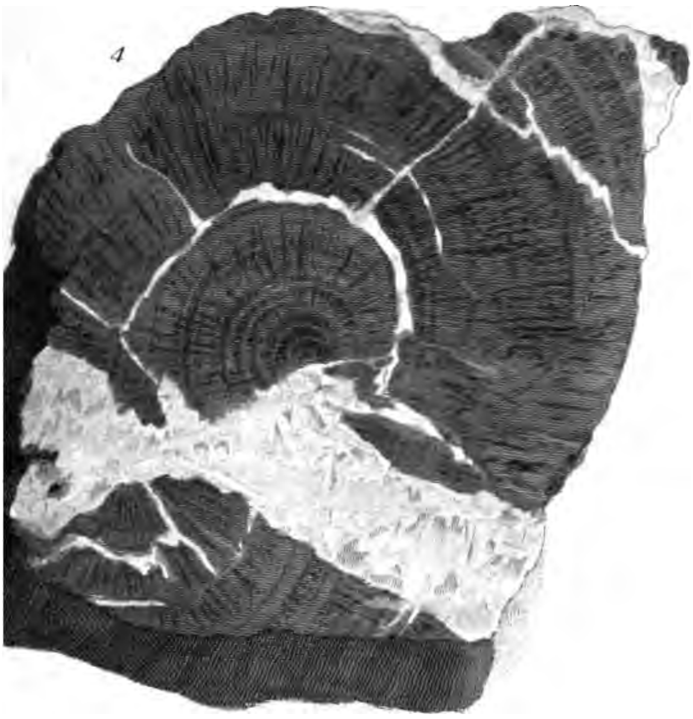

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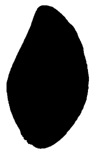

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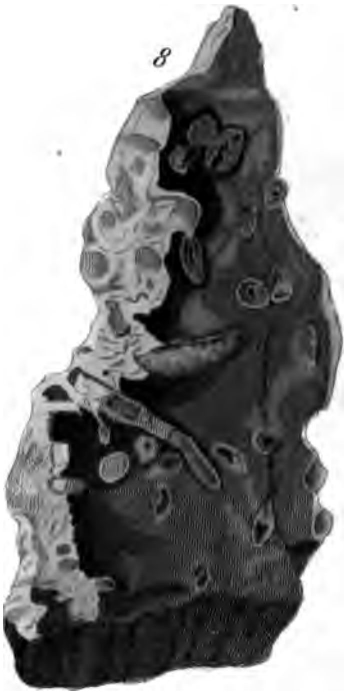

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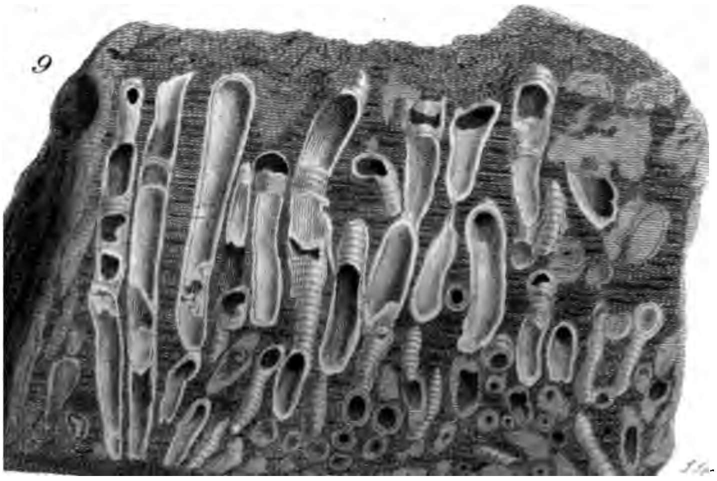

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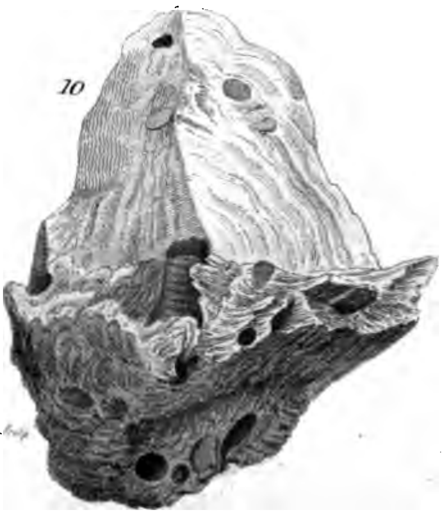

J. Sp[illegible] Sculp

PL.IX.

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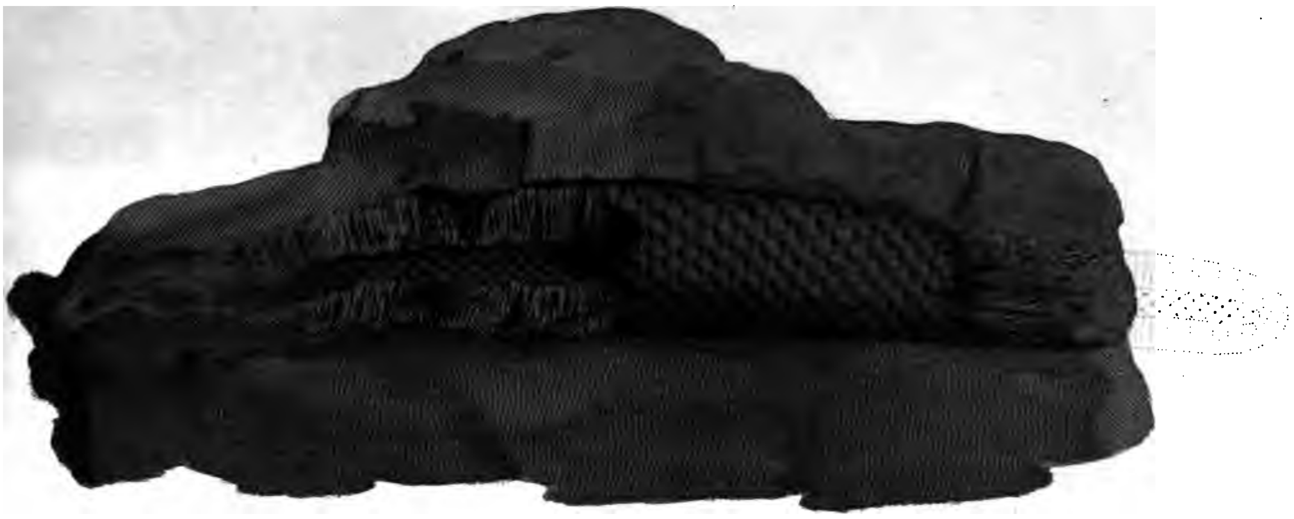

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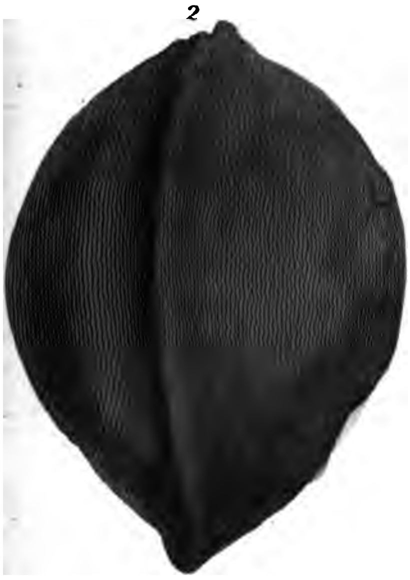

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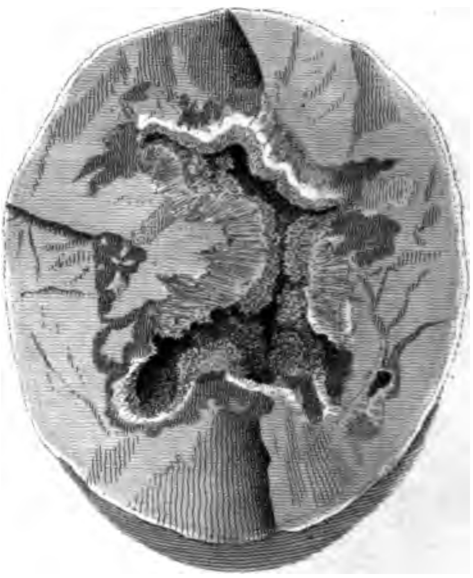

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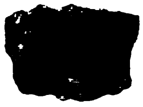

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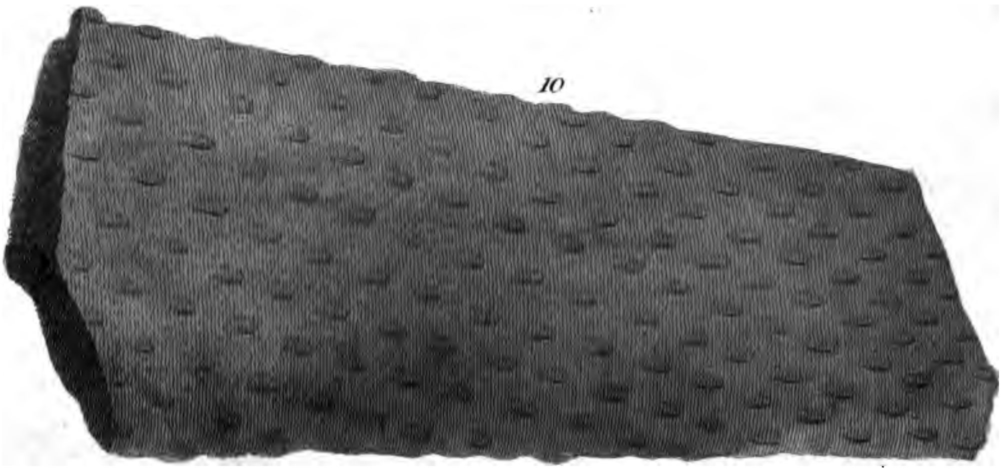

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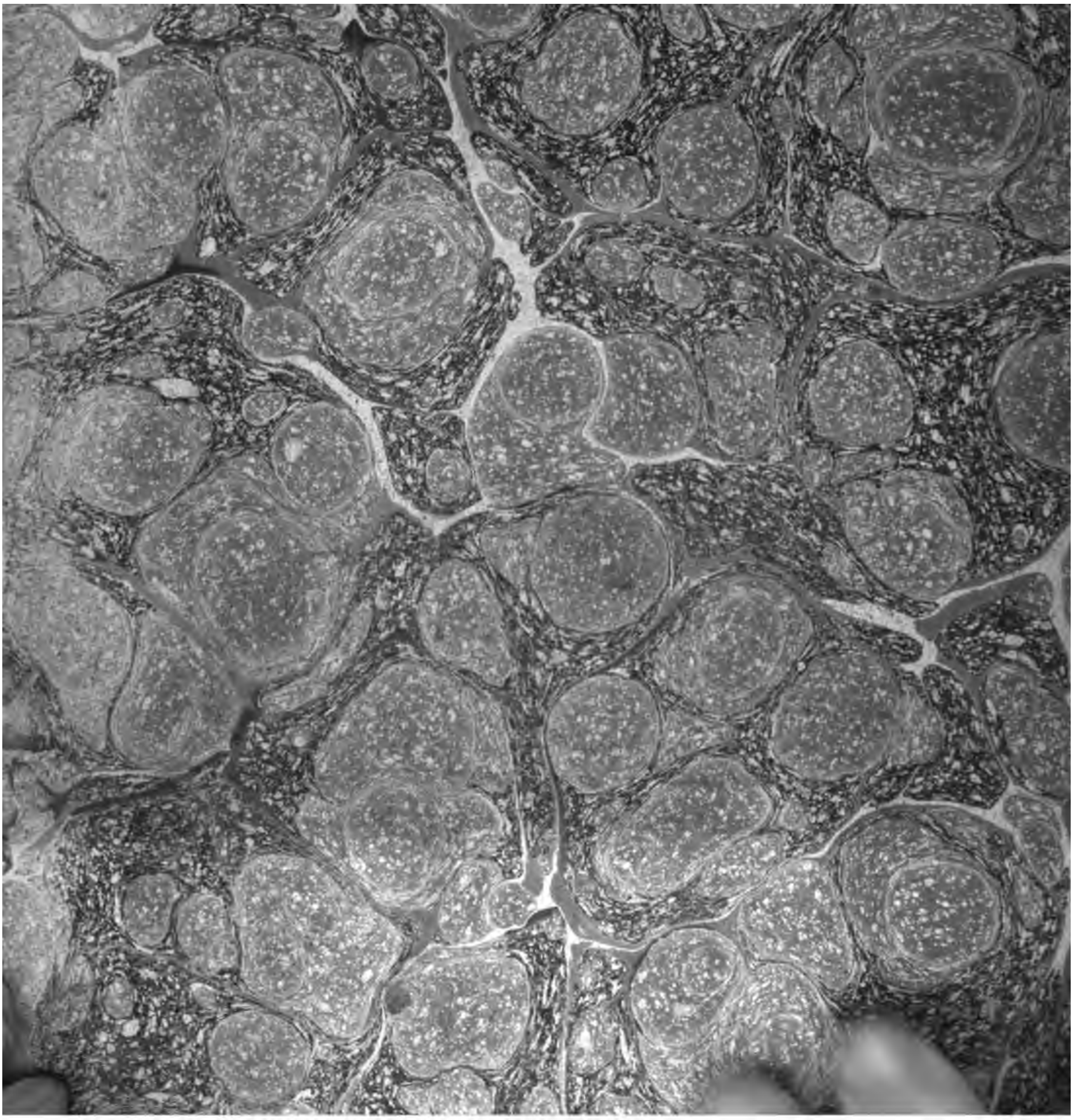

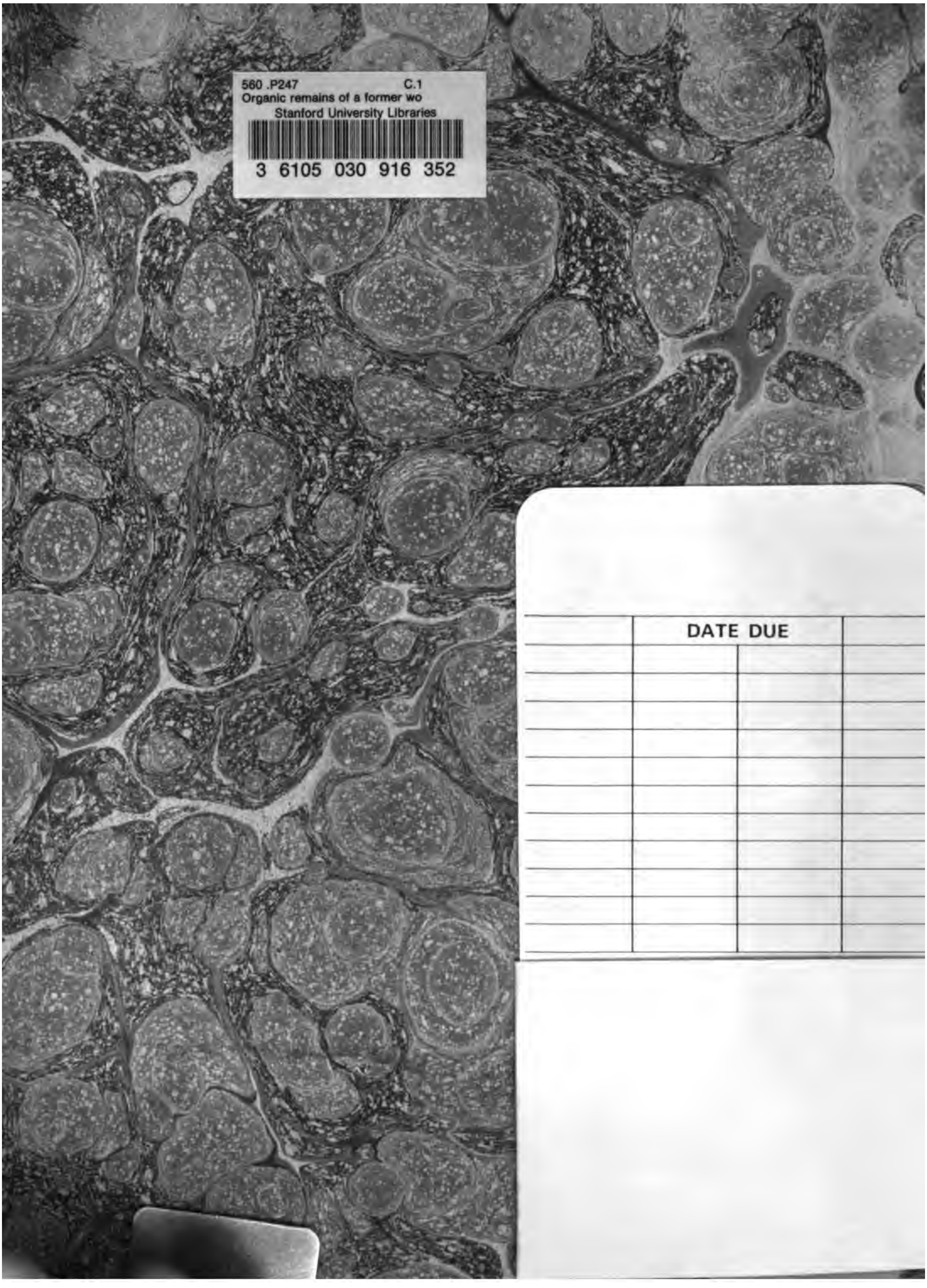

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